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WESTERN CANADIAN FLAXSEED[1]

F. H. Lehberg[2] and J. A. Anderson[3]
Grain Research Laboratory
Board of Grain Commissioners for Canada, Winnipeg, Manitoba

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The disruption of markets and transportation facilities, caused by the war, has created increased interest in the expansion of flax production in Western Canada with the object of supplying domestic demands for linseed oil. Moreover, with an exceedingly large surplus of wheat in storage, the problem of finding crops which can profitably replace some wheat acreage is of pressing importance. Among such crops, flax appears reasonably promising. In these circumstances, it seemed advisable to make available at once certain information on Western Canadian flaxseed which has been collected in this laboratory during the past few years.

The technical data given in the paper deal primarily with areas of production and the quality of the flaxseed produced in different districts. In order to present a fairly complete account of the Canadian flax situation, there are also included notes on flax varieties, grading, yield and returns per acre, world supply and demand in relation to Canadian production, and on the manufacture and uses of linseed oil.

PRODUCTION

Flaxseed was introduced into Western Canada about 1875, and because of its ability to do well on new breaking its importance increased rapidly as more and more of the prairie soil was brought under the plough. Production in Canada reached a peak in 1912 when 26 million bushels of flaxseed were produced. The graph shown in Figure 1 illustrates production trends from 1910 to 1940. It is apparent that production declined sharply during the first World War when wheat prices soared, recovered slightly in 1924, and subsequently fell rather steadily, dropping to extremely low levels in recent years. From 1933 to 1939, production failed to supply domestic requirements of approximately 2.5 million bushels, and imports of flaxseed have consequently amounted to about 1 million bushels annually.

Aside from price factors, which are considered later, two other factors have contributed principally to the decline in flax production. The crop owed its early popularity to its ability to yield well on new land, thus providing the farmer with an immediate cash return from new breaking without the necessity of fallowing for one year. As the prairies became settled, the amount of new breaking decreased, the land under cultivation became older, and weeds increased. The popularity of flax then decreased

[1] Contribution from the Grain Research Laboratory, Board of Grain Commissioners for Canada, Winnipeg, Manitoba. Published as paper No. 185 of the Associate Committee on Grain Research.
[2] Junior Chemist.
[3] Chief Chemist.

because its habit of growth makes it less able to compete with weeds than most other crops. On clean summer-fallowed land, which is suitable for flax production, most farmers prefer to grow wheat, either because it is frequently more profitable or because it is a less difficult crop to handle.

During the first decade of the century, flax appears to have been grown fairly generally throughout the crop-growing area of the western plains. In recent years, production has been concentrated mainly in certain specific localities. These are shown in the maps given in Figures 2 and 3. Figure 2 shows the origin of all samples collected for the annual flax surveys made by this laboratory during the 6 years 1934 to 1939. During each year about 200 samples were collected principally from flax shipments made during October, November and December. These samples generally represented the bulk of each crop, so that the map, showing the distribution of points from which these samples were collected, should present a fairly accurate picture of the main areas in which flax was grown during the 6-year period concerned. Figure 3 represents all cars of flax inspected in the Western Inspection Division during the whole of the last crop year, 1939–40. It therefore presents a very complete picture of areas from which the 1939 crop originated.

Approximately 65% of the total western flax acreage is in the Province of Saskatchewan, while 20% is in Manitoba, and the remaining 15% is in Alberta. In Saskatchewan, flax production is concentrated mainly in

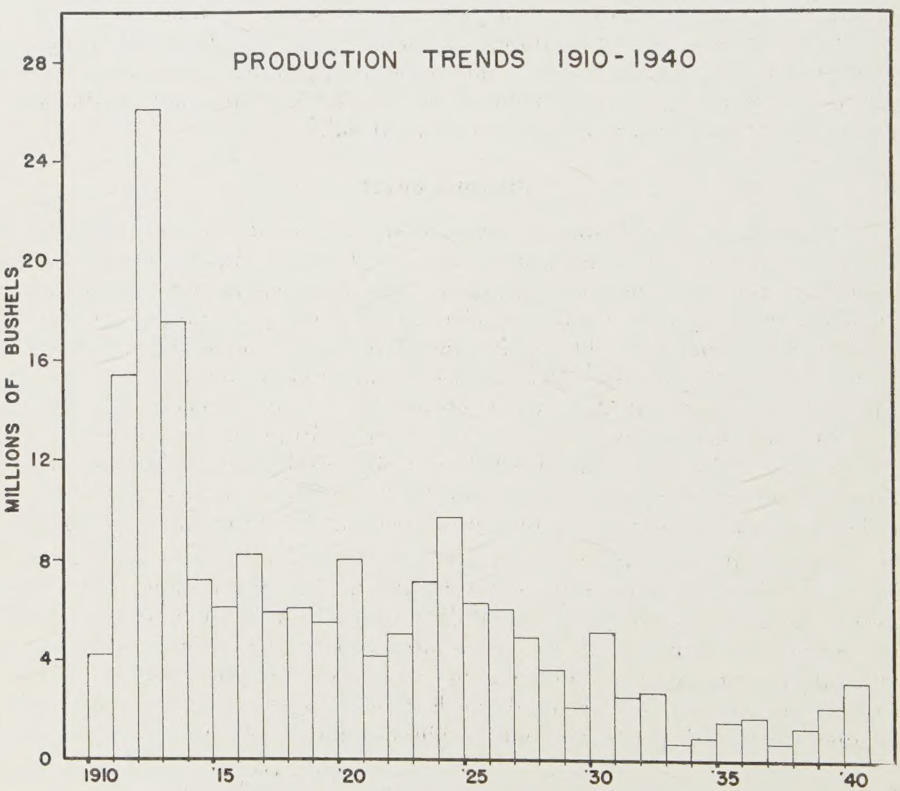

FIGURE 1. Production of flaxseed in Western Canada for the years 1910 to 1940.

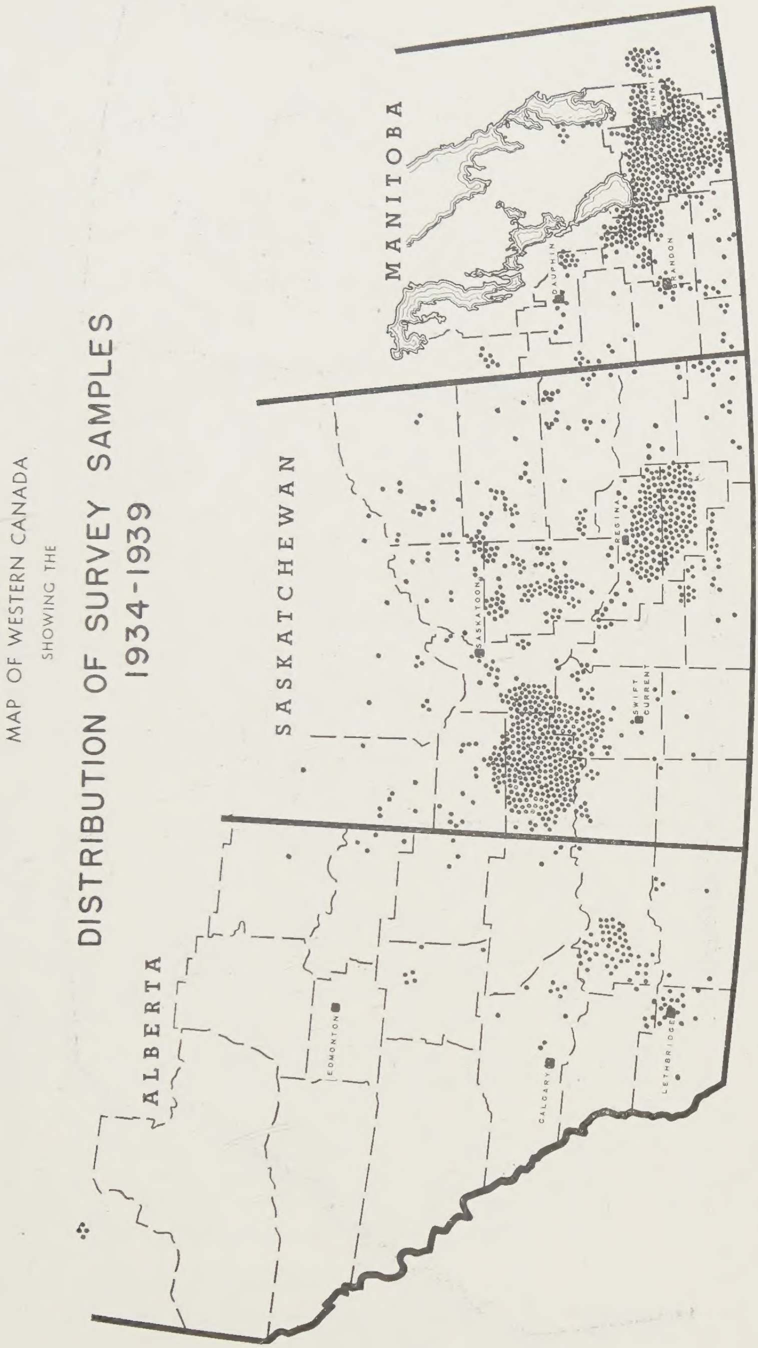

FIGURE 2. Map of Western Canada showing the geographic distribution of flaxseed samples collected for the six annual surveys, 1934 to 1939.

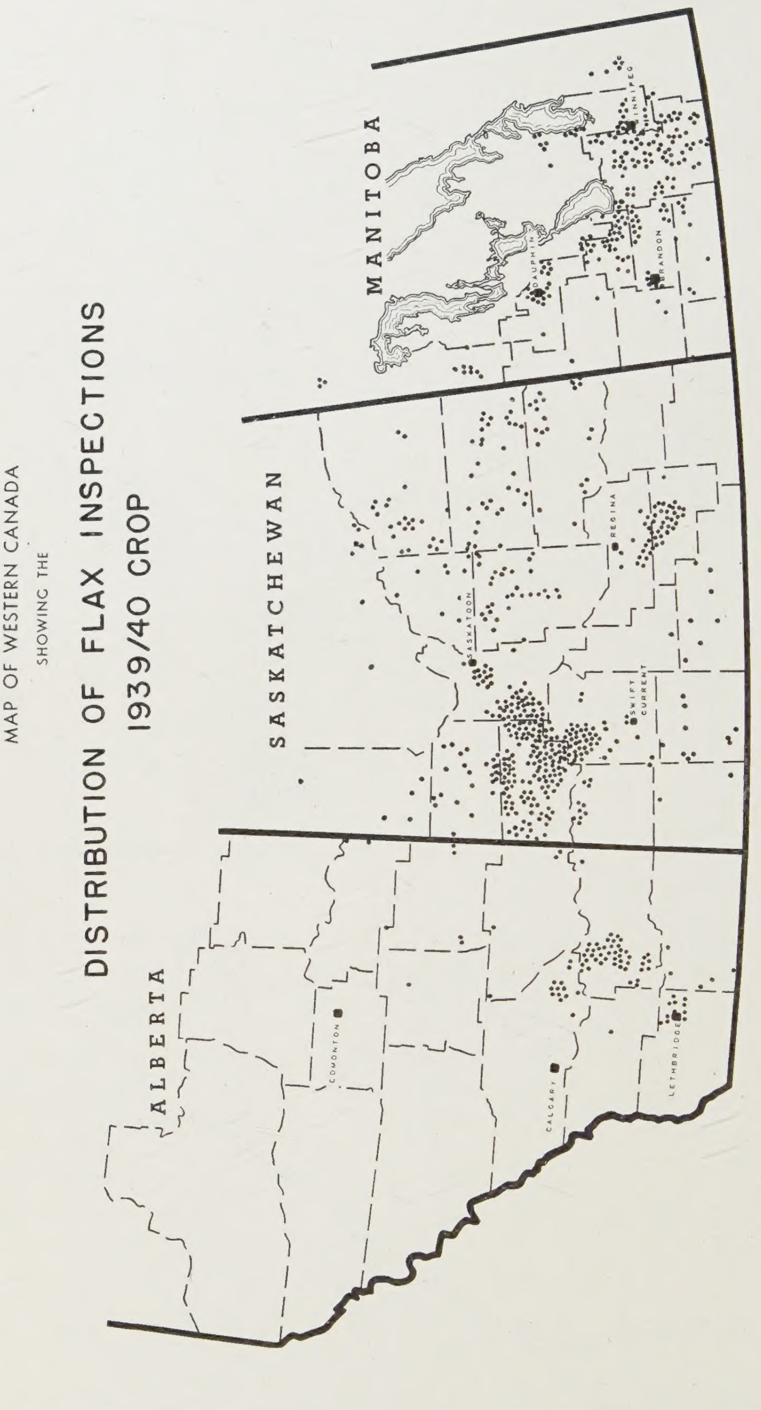

FIGURE 3. Map of Western Canada showing the origin of all cars of flax inspected in the Western Division during the 1939–40 crop year.

the Rosetown area in the west, and in the area south of Regina, with the remaining acreage scattered over the northern and eastern parts of the province. In Manitoba, the flax areas are the Red River Valley and the Portage Plains, although there has been a tendency for northern acreage to increase in recent years. Acreage in Alberta is sparse and scattered except in the irrigation areas in the south.

QUALITY

Flaxseed is valuable because it contains linseed oil, an important raw material used in the manufacture of paints, enamels, varnishes, and a variety of other products. For most of these, an oil is required which will dry rapidly to form a hard, rather than a "tacky", surface. Linseed oil is characterized by this property although its drying qualities may vary appreciably, depending upon the variety of flax and the environment under which it is grown. Thus, from the commercial viewpoint, the quality of flaxseed depends not only on oil content but also on oil quality.

Oil content can be measured quite simply, either by extracting and weighing the oil or by a more rapid method involving use of the refractometer (2). Results are reported as percentage of oil per unit of dry flaxseed.

The evaluation of quality presents greater difficulties. However, for most purposes, an adequate estimate can be obtained by determining the amount of iodine which will combine with a definite quantity of oil under standard conditions. Results are reported as iodine values in terms of Wijs' units, the unit being named after the chemist who devised the determination. The determination can be made volumetrically or by means of the more rapid refractometric technique (3, 5, 9).

The relation between iodine value and drying quality is comparatively simple. The rate at which an oil dries and the hardness of the resulting surface depend primarily on the ability of the oil to combine with oxygen from the surrounding air. As a broad generalization, it may be said that the more rapidly and completely an oil oxidizes, the more satisfactory will it be for the preparation of fast-drying paints and varnishes. Now those chemical characteristics of an oil which enable it to combine with oxygen also enable it to combine with iodine, and this latter ability can be measured much more simply and rapidly than the former. Thus, broadly speaking, the determination of iodine value provides a method of estimating the drying quality of the oil, those oils which have the highest iodine value being of the best quality.

It may be noted in passing that flaxseed produces, in addition to oil, a useful by-product known as linseed meal or cake. This is a valuable source of digestible protein and is widely used as a protein concentrate for the feeding of growing live stock and dairy cattle.

Annual Variations in Quality

For the past 6 years, annual surveys of the oil content of Western Canadian flaxseed and the iodine values of the extracted oil have been made in this laboratory. Table 1 gives the numbers of samples studied each year, together with mean oil contents and iodine values. It will be observed that oil content has varied between 41.1% (1939) and 42.8% (1937). Although the difference between these values does not appear

to be great, it is quite appreciable from the commercial viewpoint. It has been calculated that, on the average, a bushel of flaxseed containing 41.5% of oil on the dry basis, and 6% of moisture, gives a commercial yield of 19 lb. of crude linseed oil. An increase in oil content of 1% will increase the oil yield per bushel by 0.6 lb. Accordingly, it is apparent that the difference between parcels of flax containing 41.1% and 42.8% of oil is equivalent to a difference in yield of crude oil of 1 lb. per bushel.

Table 1.—Oil content and iodine value of western Canadian flaxseed for the years 1934 to 1939

Year	Number of samples	Oil content	Iodine value, Wijs' units
		%	
1934	148	41.3	184
1935	210	42.1	190
1936	232	41.3	182
1937	179	42.8	183
1938	285	41.3	187
1939	450	41.1	186
Mean	251	41.6	185

The data show that iodine value has varied between 182 units (1936) and 190 units (1935). This is a variation of 4.4% which represents an appreciable variation in the drying behaviour of the oil.

Variations in Quality Caused by Environment

Environmental factors, principally precipitation and soil type, have a considerable effect on the quality of flaxseed, more particularly on the iodine value of the expressed oil. Maps illustrating the variations in oil content and iodine value which occur in different localities are given in Figures 4 and 5. Four ranges, represented by different types of dots, are shown in each map. Each dot represents a mean value for all flax samples collected from a given station during the course of the 6 annual surveys made for the years 1934 to 1939. A total of 1,437 samples are represented, of which 480 originated in Manitoba, 851 in Saskatchewan, and 106 in Alberta.

Reference to Figure 4 will show that the predominant range for oil content is 41.0% to 41.9% (open squares) in almost all districts. There is a suggestion that higher oil contents (black squares and black dots) may tend to occur rather less frequently in southern districts but additional data are required to substantiate this hypothesis. In general, it appears that there is no area in Western Canada that tends consistently to produce flax of above-average oil content.

Figure 5 shows that there are somewhat more consistent differences between the iodine values for flaxseed from different districts. Oil quality tends to be lower in the Red River Valley in southern Manitoba, and in the district south of Regina in Saskatchewan. A study of the individual sets of data for each of the past 6 years leaves little doubt that iodine values are generally higher in the northern park belt of the prairies and in the irrigation areas. However, flax production in the park belt is

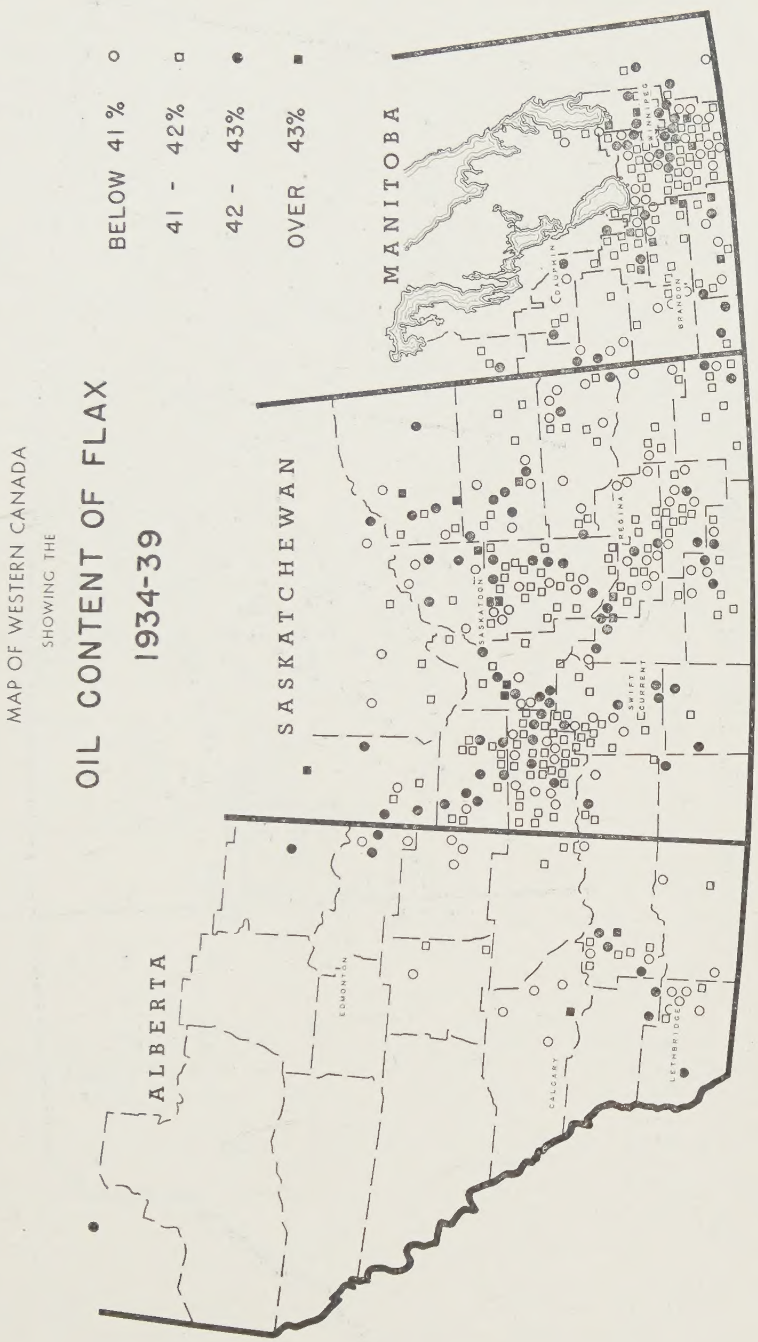

FIGURE 4. Map of Western Canada showing the oil content of flaxseed—mean for the years 1934 to 1939.

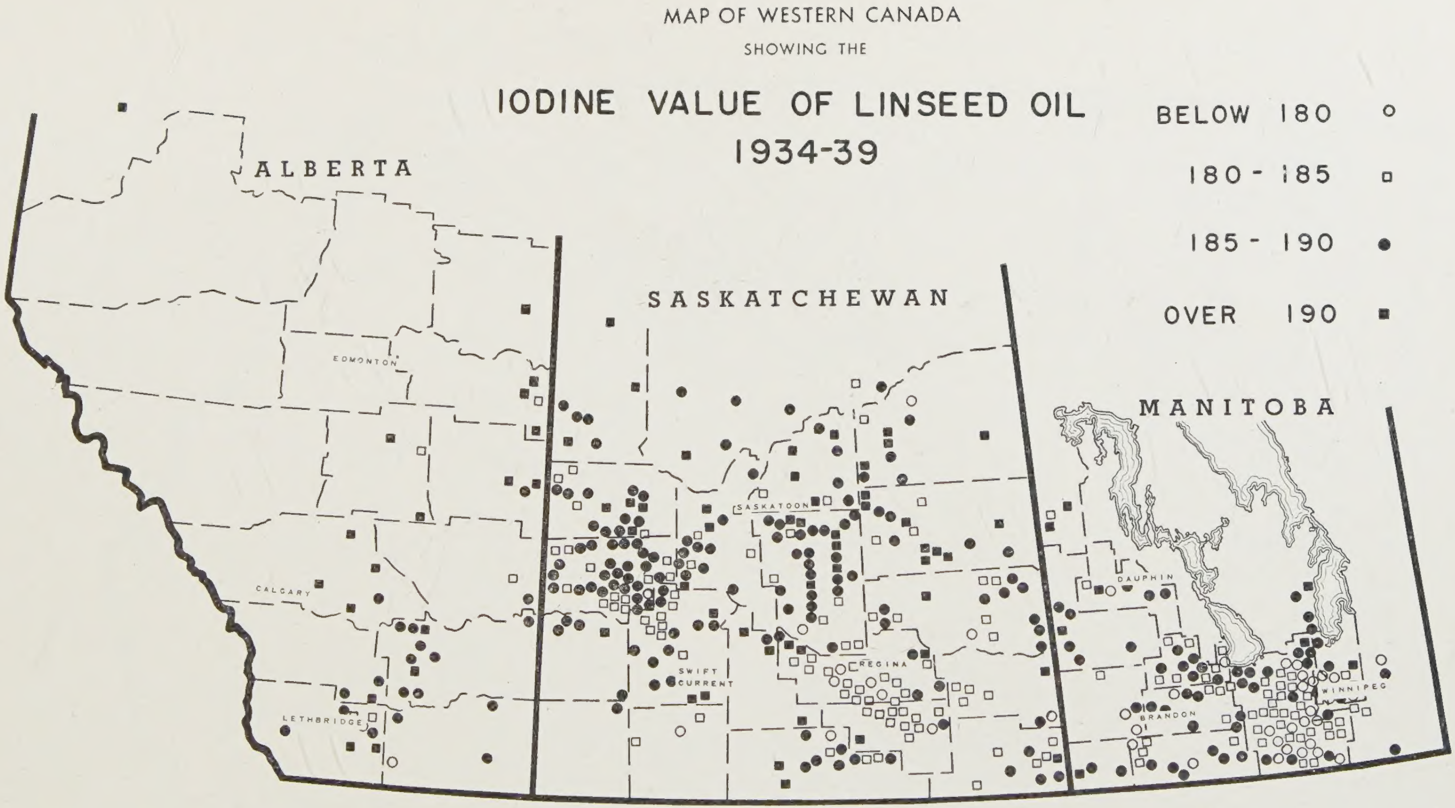

FIGURE 5. Map of Western Canada showing the iodine value of linseed oil—mean for the years 1934 to 1939.

comparatively sparse and scattered so that this area does not show to advantage in the composite map for the 6 years (Figure 5). In general, it appears that flaxseed of the best quality is produced in those areas which produce wheat of average to low protein content. It is for this reason that the substitution of flax for some wheat acreage appears to hold considerable promise.

Comparative Quality of Grades of Flaxseed

Inspection of flaxseed is compulsory in the Western Inspection Division, and all carloads arriving at inspection points are officially graded. The grades are defined in the Canada Grain Act and are differentiated on the basis of appearance, weight per bushel, dockage, damage and moisture content. For example, No. 1 Canada Western Flaxseed must have a minimum weight per bushel of 51 pounds, must be composed of mature, dry, sweet seed, and may contain not more than 12% of damaged flaxseed; whereas No. 2 Canada Western has a minimum weight per bushel of 50 pounds and may contain 25% of damaged flaxseed.

A review of the grading of flaxseed during the past 6 years shows that, on the average, 86.1% of the cars inspected in the Western Division graded No. 1 Canada Western, and that very few cars graded below No. 2 C.W., except in the crop year 1937–38 when the percentage of cars below No. 2 C.W. rose to 13.5%. The percentages of cars in each of the principal grades, for the past 6 crop years, are given in Table 2.

TABLE 2.—FLAX INSPECTION RETURNS—WESTERN GRAIN INSPECTION DIVISION—CROP YEARS 1934–35 TO 1939–40

Grade	Percentage of cars					
	1934–35	1935–36	1936–37	1937–38	1938–39	1939–40
1 C.W.	79.6	87.1	90.6	78.2	88.9	92.1
2 C.W.	14.6	8.1	6.0	8.3	9.0	1.8
3 C.W.	2.0	2.7	1.9	2.1	0.6	0.8
Other grades	3.8	2.1	1.5	11.4	1.5	5.3

Data showing the oil contents and iodine values for each of the first three grades of Western Canadian flaxseed, for each of the past 6 years, are given in Table 3. It will be observed that differences between grades

TABLE 3.—COMPARATIVE QUALITY OF GRADES OF WESTERN CANADIAN FLAXSEED FOR THE CROPS OF 1934 TO 1939

—	Grade	1934	1935	1936	1937	1938	1939
Oil content,* Percentage	1 C.W.	41.2	42.1	41.3	42.8	41.4	41.1
	2 C.W.	41.8	42.4	41.1	42.3	41.1	40.6
	3 C.W.	41.7	41.4	41.3	42.9	40.6	40.4
Iodine value, (Wijs')	1 C.W.	183.8	189.8	181.7	182.6	186.5	185.9
	2 C.W.	183.8	191.5	180.3	182.4	186.3	185.9
	3 C.W.	182.0	194.6	181.4	183.4	189.4	184.0

*Reported on a dry-matter basis.

are comparatively small and that there is little tendency for the oil contents or iodine values to decrease with decreasing grade. This is to be expected since, according to the Canada Grain Act, neither oil content nor iodine value is a grading factor. In passing, it may be mentioned that to introduce either of these properties as a grading factor would present considerable difficulty, since neither can be assessed without recourse to a laboratory determination requiring considerable time.

Comparative Quality of Flaxseed Varieties

At present there are three main varieties of flaxseed in commercial production in Western Canada, namely, Bison, Redwing and Crown. Bison is resistant to flax wilt, and Redwing is also moderately resistant to this disease. On the other hand, although it has been commonly stated in the literature that both these varieties are resistant to rust, more recent investigations show that both are actually susceptible to many forms of flax rust (1). Bison is somewhat late in maturing. It produces a rather tall plant, giving a good yield of seed containing a relatively high percentage of oil of fair quality. The seed of Redwing is smaller and gives a lower yield of oil, but the oil is superior in quality to that of Bison. Redwing has the advantage of early maturity, which makes it particularly suitable for northern areas in which early frost is a factor of importance. Crown has the disadvantage of being susceptible to both wilt and rust, and for this reason it will probably be displaced entirely in the near future. Its quality characteristics are similar to those of Bison.

The best available Canadian data on the comparative qualities of these three varieties of flaxseed are the results of tests made on samples grown at Indian Head, Saskatchewan, and Beaverlodge, Alberta, during each of the past 4 years. Mean data on oil content and iodine value are given in Table 4. It is apparent that the quality characteristics of Bison and Crown are almost identical, whereas Redwing yields less of a better quality oil.

Table 4.—Oil content and iodine value of Bison, Redwing and Crown varieties

Variety	Oil content	Iodine value, (Wijs')
	%	
Bison	41.5	187.9
Redwing	40.3	192.8
Crown	41.5	188.3

Canadian plant breeders are striving to produce better varieties of flax for Western Canada. Among the available parent materials, the common or "Russian" varieties are generally undesirable because of their susceptibility to wilt. Most strains of Argentine flax are immune to rust and many are resistant to wilt, but those examined to date are not sufficiently early to suit the short growing season of the prairies. The Indian, Abyssinian, and yellow-seeded types contain a high percentage of good quality oil, but are short and much branched and are generally inferior to

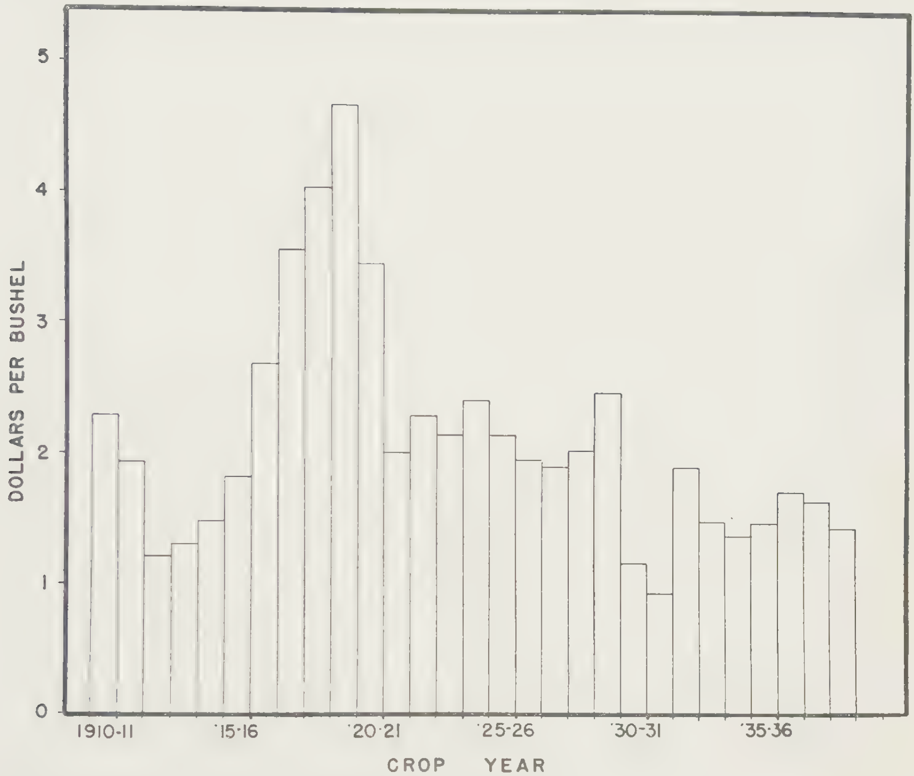

FIGURE 6. Average price of Western Canadian flax for the crop years 1910–11 to 1938–39.

Bison, Redwing and Crown both in disease resistance and in yield per acre. The problem of the plant breeders is to combine in one variety the desirable characteristics of several different types.

PRICES AND RETURNS PER ACRE

A graph showing the annual fluctuations in the average price of Canadian flaxseed appears in Figure 6. Prices rose sharply during the first World War and reached an average price of $4.66 for the 1919–20 crop year. A return to an average price of about $2 per bushel had taken place by 1923–24; since when prices have declined slightly with low levels occurring during the crop years of 1930–31 and 1931–32 when the effects of a serious business depression were being widely felt.

It appears that the price of flaxseed is determined largely by the demand for its chief product, linseed oil. This demand, unlike that for wheat, is subject to wide fluctuations. It appears to be correlated with general business activity, particularly in the building industry which uses large amounts of paints and related products. The demand for linseed meal and the scarcity or abundance of other feeds also affect flax prices. Ratcliffe (6), who studied factors affecting flax prices in North Dakota, found that only a slight relationship existed between the size of the United States crop and price. On the other hand, he found that available supplies and crop conditions in Argentina, the country exporting most flax, had a decided influence on world flax prices.

The graph in Figure 7 shows that the average yield per acre for western flax has varied from a high of 13.2 bushels in 1915 to a low of 2.9 bushels in 1937. A general relation between flax yields and precipitation generally occurs, yields tending to be higher in wet seasons and lower under drought conditions.

The average yield in bushels per acre of flax is less than half that of wheat and about one-third of the average yield of barley. In order that flax may be reasonably attractive to the farmer, flax prices must therefore be at least twice as high as wheat prices. When this price relationship prevails, returns per acre for wheat and flax will not be widely different.

A comparison of yields and gross returns per acre, in dollars, of flax, wheat, oats and barley, is given in Tables 5 and 6. The data represent

Table 5.—Comparison of average yield and dollar return per acre of flax, wheat, oats and barley in the prairie provinces—1930 to 1939

Crop	Manitoba		Saskatchewan		Alberta	
	Yield per acre	Return (gross)*	Yield per acre	Return (gross)*	Yield per acre	Return (gross)*
	bu.	$	bu.	$	bu.	$
Flax	6.7	8.67	4.4	5.55	7.4	9.17
Wheat	14.4	10.21	10.1	6.80	15.4	10.00
Oats	23.1	7.20	19.4	5.65	30.2	8.38
Barley	19.0	8.15	15.1	6.05	22.9	8.73

*Freight rate to Fort William deducted.

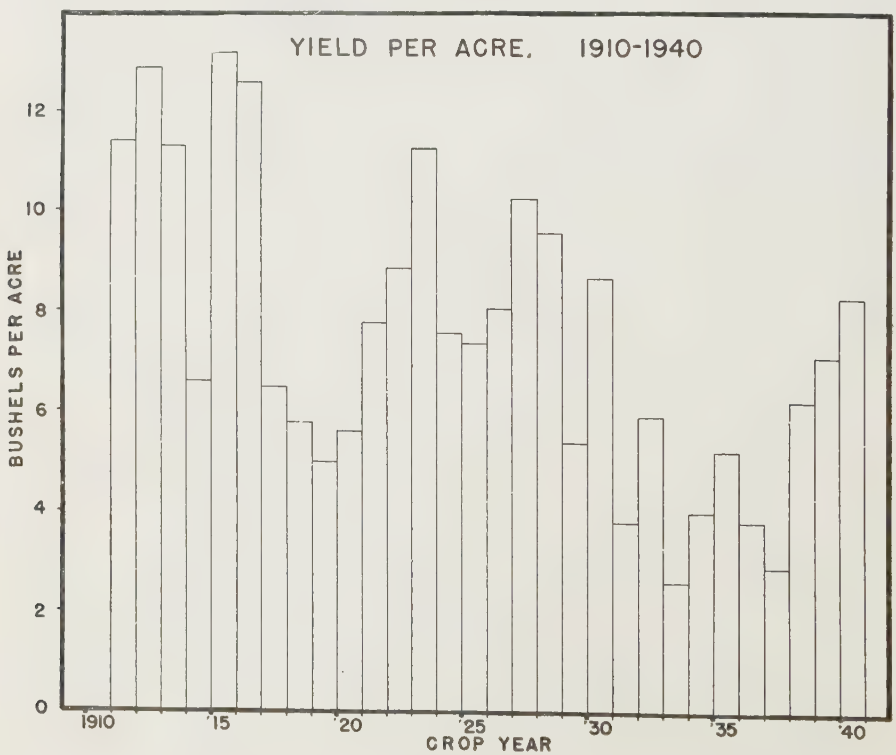

Figure 7. Yields per acre of flaxseed in Western Canada for the years 1910 to 1940.

TABLE 6.—DOLLAR RETURN PER ACRE FOR CROP-REPORTING DISTRICTS IN SASKATCHEWAN* —1930 TO 1939

—	Crop district								
	1	2	3	4	5	6	7	8	9
	$	$	$	$	$	$	$	$	$
Wheat	5.07	5.39	4.51	5.18	10.73	6.57	7.37	12.26	10.76
Oats	3.18	3.76	3.29	3.82	8.09	4.89	5.79	9.23	8.27
Barley	3.59	4.32	3.20	3.93	8.08	5.09	5.29	9.17	7.78
Flax *(a)*	4.10	4.82	3.78	4.51	9.18	5.54	7.42	10.46	10.39
(b)	4.82	5.68	4.46	5.32	10.81	6.53	8.76	12.34	12.27

*Freight rate to Fort William deducted.
(a) Ten-year average price of flax.
(b) Price of flax assumed to be twice the 10-year average price for wheat.

the means for the 10-year period, 1930 to 1939, and separate figures are given for each of the three Prairie Provinces. The figures were computed from the Grain Trade Year Books (7) and various government reports; all prices are quoted basis Fort William, less average freight rate, and in terms of the following grades: No. 1 C.W. flaxseed; No. 1 Northern wheat; No. 3 Extra C.W. Six-row barley; and No. 2 C.W. oats. Table 6 gives similar comparisons of returns per acre for each of the crop districts in Saskatchewan. For this table, freight rates were computed for each crop district, and the returns per acre for flax were calculated on two bases: *(a)* 10-year average price of flax, and *(b)* price of flax assumed to be twice the 10-year average price for wheat.

Table 5 shows that the returns per acre for wheat were considerably higher than for flax in all three provinces. Flax proved to be a better cash crop than either oats or barley in Manitoba and Alberta, the reverse being true for Saskatchewan.

It will be observed in Table 6 that wheat gives the highest return per acre in 8 of the 9 crop districts in Saskatchewan, flax being better in Crop District 7. Flax was a better cash crop than either oats or barley in all 9 crop districts. It is also apparent that if the price of flax is taken as twice that of wheat, flax provides a better return per acre than wheat in 6 of the 9 districts. On this basis (flax price twice wheat price), the average returns per acre for the whole province are $6.80 for wheat and $6.54 for flax.

It is interesting to note that in recent years the tendency has been for flax to concentrate in Crop District 7 in Saskatchewan, or the west-central area. This trend appears to be explained by the fact that in this area flax tends to give a better average return per acre than wheat.

Some incongruity is apparent in the figures in Tables 5 and 6 showing the relations between returns for flax and returns for other coarse grains. In Table 5 the average returns for flax in Saskatchewan are shown to be lower than those for barley and oats, whereas Table 6 shows that flax gives better returns than the other two crops in each individual crop district. The explanation of this apparent discrepancy is that in Saskatchewan, as a whole, a considerable proportion of the flax is grown in southern districts where yields are lower, while oat and barley acreage is predom-

inantly in the higher yielding northern districts. Thus, in dealing with average returns per acre for the whole province, an apparent advantage is given to oats and barley. This disappears when the more accurate method of making comparisons within individual crop districts is adopted.

The accuracy of the comparisons is also affected by the average grade received for each kind of crop in each crop district. The grade selected for each crop, for purposes of our calculations, represents the highest grade containing a considerable proportion of the crop in an average year. With the limitations noted in the last paragraph, this basis is probably reasonably satisfactory for the comparison of provincial means. However, it is less satisfactory for crop district means. Thus it is well known that in the northern crop districts in Saskatchewan, the average grade for wheat is lower than No. 1 Northern, the chief degrading factors being frost and immaturity. These factors also affect oats, barley and flax, but probably to a somewhat lesser extent. Consequently, it appears that for northern districts, comparisons, based on the grades listed earlier, tend to favour wheat unduly. Unfortunately, data on average grades for each crop district do not appear to be available, so that more accurate comparisons of returns per acre for wheat, flax, oats, and barley, cannot be made.

PRESENT SITUATION AND FUTURE PROSPECTS

Table 7 contains data on world production of flax, arranged according to continents and principal producing countries (4, 8). These, listed in order of their importance, are: Argentina, U.S.S.R., India, United States, Canada and Uruguay. There have been considerable fluctuations in production in most countries during the past 10 years and there is little evidence of any marked trend in individual countries. During the first half of the last decade, production declined appreciably in the United States. During the past 2 years, more favourable prices and the protective measures introduced under the A.A.A. program have caused an increase in flax acreage, with the result that production in 1940 in the United States amounted to over 30 million bushels as compared with an average of 10 million bushels for the past 6 years. Production in Canada fell below $\frac{3}{4}$ million bushels in 1933 and again in 1937 but surpassed 3 million bushels in 1940.

Average world production was 111 million bushels for the 5-year period 1909 to 1913, increased to 150 million for the 5 years 1924 to 1928, reached a maximum of 165 million in 1931, and has subsequently averaged about 135 million bushels. Since Canada disappeared from the list some 10 years ago, the principal countries exporting flaxseed have been Argentina, India and Uruguay. Russia and the United States have consumed most of their own flaxseed. During the past 15 years nearly one-half of the total world supply of flaxseed has been produced in Argentina. About 90% of that country's production is exported, and this represents over 75% of the world trade for the past decade. The positions of India and Uruguay are demonstrated by figures for their exports during the period 1932 to 1936, which represented about 12.1% and 3.6% of world exports respectively.

TABLE 7.—WORLD PRODUCTION OF FLAXSEED
(In bushels of 56 pounds 000 omitted)

Continent	Country	Average 1909–13	Average 1924–28	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939
		bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.
Europe	All European	7,560	7,603	9,765	7,911	5,867	4,171	5,001	6,310	8,623	10,011	9,763	8,771	9,055
	U.S.S.R.	19,164	22,168*	28,066	28,350	33,221	31,402	29,311	27,023	29,137	30,319†	—	—	—
North and Central America	Canada	12,041	6,138	2,060	5,069	2,465	2,719	632	910	1,563	1,730	694	1,315	2,169
	U.S.A.	18,546	23,278	15,924	21,673	11,755	11,511	6,904	5,661	14,520	5,273	7,089	8,152	20,330
	Other countries	1,268	75	24	39	75	142	71	78	78	106	—	—	—
South America	Argentina	31,126	72,411	50,004	78,342	89,067	62,006	62,595	79,720	59,445	76,200	60,604	55,509	44,368
	Uruguay	953	1,906	3,216	5,056	4,841	1,475	2,876	3,402	3,007	3,011	3,728	4,425	4,693
	Other countries	16	51	44	63	63	4	35	24	24	35	—	—	—
Asia	British India	19,876	15,837	14,080	16,840	16,640	18,160	17,600	16,080	17,920	16,640	17,800	19,440	18,800
	Other countries	94	315	409	280	315	287	413	315	409	504	—	—	—
Africa	—	354	598	504	532	1,051	476	20	461	358	547	—	—	—
Oceania	—	47	78	197	192	28	8	31	39	31	12	—	—	—
World total		111,045	150,458	124,293	164,350	165,388	132,364	125,489	140,053	135,115	144,418	—	—	—

*Average of 4 years.
†Estimated.

The net imports of flaxseed to the principal importing countries are shown in Table 8. Among these countries, the Netherlands occupy first place with an average importation of 14.0 million bushels per annum, as calculated for the period 1932–36. Second place is held by the United States with 13.8 million bushels annually. The United Kingdom is also a large importer, taking an average of 10.6 million bushels.

TABLE 8.—NET IMPORTS OF FLAXSEED TO PRINCIPAL IMPORTING COUNTRIES

(In bushels of 56 pounds—000 omitted)

Country	Average (1924–28)	Average (1932–36)
	bu.	bu.
Netherlands	12,911	14,043
U.S.A.	19,014	13,778
Germany	12,084	12,485
United Kingdom	14,722	10,567
France	6,961	10,012
Belgium	3,603	4,590

When flax was widely grown on the prairies, substantial quantities of Canadian flaxseed were exported. Prior to 1929, when Canada was exporting 2 or 3 million bushels per year, most of this flaxseed went to the United States. However, since the duty of 65 cents per bushel was placed on imports from Canada in 1930, this trade has vanished almost entirely. For a number of years, production has been insufficient to meet domestic requirements, and for the past decade an average of nearly 1 million bushels of flaxseed has been imported into Canada annually, principally from Argentina. There are many factors responsible for this situation. Among these, price relations, the decrease in new breaking, and the increase in the weed problem as cultivation continues for long periods, are probably most important. In addition, the growing of varieties which are susceptible to the soil-borne disease of flax wilt, and the consequent mistaken assumption that flax is "hard on the soil", have combined to make flax unpopular.

Such data as are available suggest that domestic requirements are approximately 2.5 million bushels per annum, but will fluctuate somewhat depending upon general industrial activity. Flax acreage in Canada appears to depend upon the farmers' opinions of the probable price relations between flax and wheat. For some time past, the price ratio has favoured wheat but more recently the price of flax has been more than twice that of wheat, at which ratio the growing of flax offers to become attractive.

During the first World War the demand for flax and its price rose considerably. At the time of writing, it appears that a similar trend may be caused by the present war, and various authorities are recommending an increase in flax acreage in Western Canada. However, there are several factors which militate against substantial increases in demand and price. Glycerine for explosives can now be made synthetically at an economical price, and a large increase in demand for glycerine from oils is not antici-

pated. World supplies of flax are considerable and large surpluses of feed grains also exist. On the other hand, transportation difficulties have been enormously increased and this, together with the disruption of normal markets caused by the blockade, makes the location of surpluses an important factor. A continuation of high freight rates from Argentina, and uncertain shipping facilities, may make Western Canadian flaxseed attractive to United States purchasers in spite of the heavy duty. Moreover, the high quality of the oil from Canadian flaxseed increases its value, owing to its ability to improve the drying quality of linseed oil produced in the United States.

The long range possibilities for flax are still more difficult to foresee. After many years of sales promotion on the part of industries interested in substitute oils and synthetics, linseed oil still remains the principal oil used in the paint and varnish industry. In the United States, 40% of the available linseed oil is used in these industries, while a like amount is used by painters for thinning and mixing. The linoleum and oilcloth industry holds second place with a consumption of 11.5% of the total. With the increasing scarcity of harder drying oils, such as tung, caused principally by the war in the Far East, there is a possibility of increased demands for linseed oil. Moreover, the danger of ultimate displacement of linseed oil by harder drying oils will probably be reduced by the attention now being given to research looking to the improvement of linseed oil, with the object of producing protective coatings in which tung oil was previously used.

MANUFACTURE AND USES OF LINSEED OIL IN CANADA

Although it is somewhat outside the scope of this paper, it seemed probable that many readers would appreciate a brief note on the manufacture and uses of linseed oil.

There are 8 flaxseed crushing mills operating in Canada: 3 in Quebec, 2 in Ontario, 2 in Manitoba, and 1 in Alberta. In these mills, raw linseed oil is obtained from flaxseed both by the crushing and expeller methods. In the former method, the ground seed is first cooked with steam at a temperature of 170° to 180° F., and subsequently moulded into slabs which are subjected to pressure in a hydraulic press. The oil exudes at the edges of the cake and is pumped away and filtered. In the more modern expeller process, the whole seed is fed into hardened steel cylinders in which revolving screws subject the material to a gradually increasing pressure. The raw oil flows through perforations in the cylinder. The average expeller press has a greater capacity than the hydraulic press; on the other hand, the latter has the advantage of extracting a slightly larger percentage of oil.

Raw linseed oil is used in the manufacture of soaps and putty, but for most other purposes it must be subjected to further processing. It is refined by hot or cold treatment either with alkali or acid. The former process removes the fatty acids and produces an alkali-refined oil used for the preparation of varnish. Acid refining produces a partially bleached oil by destroying considerable amounts of natural pigments and by coagulation of gums and resins. The refined oil may be bleached further

with fuller's earth or activated charcoal, processes which are also applied to raw oils. Acid refined oils have a higher acid number which confers a low surface tension, making them specially suited for wetting and grinding purposes. They are used in the manufacture of lead paints and are also an intermediate product in the preparation of modified oils.

The bleached and refined oils differ little in constitution from the raw oils. Further processing involves oxidation or polymerization with resulting changes in the characteristics of the oil. Oxidized oils are of two types, "boiled" and "blown". The former are made by heating at 100° to 150° C.; the resulting partial oxidation increases the speed with which the oil dries. These oils are used principally in paint manufacture but also in the water-proofing of tarpaulins and in oiling silks. A higher degree of oxidation is exhibited by "blown" oils in the processing of which air is bubbled through the heated oil after addition of specific driers. "Blown" oils are used in the making of flat and gloss paints, linoleum, oilcloth and patent leather.

"Stand oils" are prepared by treating alkali-refined varnish oil at temperatures of 275° to 300° C. for several hours. A rearrangement of the structure takes place with the production of larger molecules and a resulting improvement in drying speed and hardness of the dried surface. Driers and resins are frequently incorporated during or after the heat treatment. The processing required in preparing "stand oils" makes them expensive, but they have superior properties for the preparation of printers' inks, enamels, litho varnishes, and other specialized protective coatings having a quick-drying hard finish.

The processed oils described above include only the principal types manufactured. In this paper, no attempt can be made to describe in detail the various individual kinds of oil produced from raw linseed oil, or to list the large number of specialized products in which these oils are used.

SUMMARY

Surveys made by the Grain Research Laboratory during 1934 to 1939 show that the main flax-producing areas in Western Canada are: the Rosetown district in west-central Saskatchewan, the Red River Valley and Portage Plains in Manitoba, a district south of Regina in Saskatchewan, and the irrigation districts in Alberta. Production in the northern park belt is sparse and scattered but increasing.

There is appreciable inter-annual variation in oil content and drying quality of the expressed oil. Both quantity and quality of oil depend on environmental factors, and there are indications that oil of better quality is yielded by flax grown in the park belt where rainfall is higher and the protein content of wheat is generally average or lower. Grades of flax differ little in oil content or drying quality, but appreciable differences exist between varieties.

Production, yields, prices, returns per acre and world movements of flaxseed are discussed briefly. It is concluded that the outlook for Canadian flax producers is reasonably favourable.

A note is included on the manufacture and uses of linseed oil.

ACKNOWLEDGMENTS

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PATHOGENICITY TESTS ON SUGAR BEETS OF RANDOM ISOLATES OF *RHIZOCTONIA SOLANI* KÜHN FROM POTATO[1]

G. B. SANFORD[2]

Dominion Laboratory of Plant Pathology, Edmonton, Alberta

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It is well known that *Rhizoctonia Solani* Kühn attacks and seriously injures the underground parts of various economic host plants, including potatoes, sugar beets, beans, peas, and to some extent wheat, and that it is also important as a damping-off parasite of seedlings of many kinds of plants. The question of whether one kind of crop susceptible to *R. Solani* can safely follow another with respect to disease is obviously important to growers. The purpose of this paper is to discuss this problem as it relates to the sequence of potatoes and sugar beets, which crops often follow each other in the irrigated sections of southern Alberta and elsewhere.

Until now the sugar beet crop in southern Alberta has been remarkably free from rootrot caused by *R. Solani*, which is not surprising in view of the relative newness of the land used. On the other hand, the introduction and increase in future of parasitic races of *R. Solani* may be expected. Consequently, at this stage it is highly important to ascertain whether the strains of *R. Solani* which commonly occur on the potato in the form of sclerotia, the Corticium stage, and in stem lesions, will attack and destroy large roots of sugar beets, and also whether strains pathogenic to the latter are increased by the potato crop. LeClerg (1), 1934, working in Minnesota, concluded that rhizoctonia rootrot of sugar beets is probably caused by strains of *R. Solani* distinct pathogenically from those on potato. He based this conclusion on comparative pathogenicity tests on sugar beets of 27 isolates obtained from lesions on the potato stems and 51 isolates from rotted sugar beet roots. However, in 1939, LeClerg (2) obtained an isolate from potato that was pathogenic to the sugar beet root.

MATERIALS AND METHODS

A total of 150 isolates of *R. Solani* were tested for pathogenicity to large roots of sugar beets growing in the field. Three of these isolates, namely S.B. 13, 33, and 69, were obtained from Dr. E. L. LeClerg, and used as controls because of their known ability to rot large roots of sugar beet. With the exception of one pathogenic isolate from beans, and another from peas, all the isolates were obtained from the potato plant. Ten of the 148 isolates from potato were from single basidiospores of the *Corticium* stage, 10 from lesions on the stem, and 128 from random sclerotia on potato tubers. The isolates were probably representative of the fungus in four different potato fields in the Edmonton district. All isolates from potato have been tested many times for their relative pathogenicity on potato stems, and it is of particular interest that approximately 33% of the isolates from sclerotia, 87% of those from basidiospores, and 25%

[1] Contribution No. 642, from the Division of Botany and Plant Pathology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.
[2] Pathologist-in-Charge.

TABLE 1.—DISEASE REACTION OF LARGE SUGAR BEET ROOTS TO RANDOM ISOLATES OF *Rhizoctonia Solani* FROM POTATO

Isolates		Pathogenicity	
Origin	Number	Potato	Sugar Beet
		%	%
Sclerotia on potato tubers	124	33	0
Lesions on potato stems	16	25	0
Basidiospores on potato stems	8	87.5	0
Bean stem	1	0	0
Pea stem	1	0	0
LeClerg's isolates* S.B. Nos. 13, 33 and 69	3	0	100

(All non-inoculated controls were disease free.)

*From diseased sugar beet roots.

of those from stems, were apparently unable to produce lesions, while only 12% of those from basidiospores, and 25% of the isolates from stem lesions proved to be pathogenic in any degree (3).

Inoculum of each of the isolates was increased aseptically in steam sterilized Edmonton black loam. A small quantity of the inoculum was folded in a thin layer of cotton and placed approximately 3½ inches below grown level, next to each of 10, large, unwounded roots of sugar beet. The average diameter of the roots was approximately 3½ inches. The soil temperature was recorded by a soil thermograph.

The results of the test during the 3 years, 1938, 1939, and 1940, and the origin of the isolates, are given in Table 1.

RESULTS

Owing to the fact that none of the 148 isolates from potato, or the 2 pea and bean isolates, gave any evidence of being able to attack the roots of large sugar beets, the information obtained during the 3 years is briefly summarized in Table 1. The virulence, or lack of pathogenicity, as the case may be, of the isolates on potato stems has been shown previously (3). It will be recalled that a fairly high percentage of these exhibited only a very mild virulence, and surprisingly few were really virulent. However, even the very virulent ones failed to attack the sugar beet roots. Complete killing of the beet plants each year by the three LeClerg isolates (Figure 1) is evidence that the environmental conditions for the experiment were excellent and it is concluded that all the random isolates tested are not pathogenic to the roots of sugar beets.

LeClerg (1) found that a soil temperature of approximately 25 to 33° C. was most favourable for the development of Rhizoctonia rootrot of sugar beets. In this experiment the average soil temperature during 20 days after inoculation was as follows: 1938, 15° C., range 5 to 24° C.; 1939, 15° C., range 5 to 20° C.; and for 1940, 12° C., range 9 to 20° C.

FIGURE 1. Left: Sugar beet roots killed by Isolate SB–69, obtained from sugar beet by Dr. E. L. LeClerg. Right: Non-inoculated control.

DISCUSSION

From the evidence submitted it is clear that the 148 isolates from potato were all non-pathogenic to sugar beets under environmental conditions that must have been satisfactory for the test. However, only after a thorough test on potato stems of an equal or adequate number of random isolates, known to rot the sugar beet root, could one conclude that all strains of *R. Solani* which attack potato are pathogenically distinct from those that cause rootrot of sugar beets. On the other hand, if one takes into account the evidence supplied by the work of LeClerg, and also by this study, a high degree of specificity probably exists between isolates pathogenic to the two hosts mentioned.

It is of special interest that this pathogen was able to rot large roots of sugar beets in about 20 days at average soil temperatures of 12 and 15° C. This fact shows that severe damage from rootrot could occur under Alberta conditions.

There remains the practical question whether strains of *R. Solani*, pathogenic only to sugar beets, or only to potatoes, would be increased by either of these crops. There would seem no biological obstacle to a natural increase or persistence of such strains in the form of sclerotia on potato tubers, or vegetatively in the soil, or by the *Corticium* stage on potato stems and petioles of beet leaves. It is probable that the sclerotia that form on potato tubers would be removed from the field. The *Corticium* stage seems the most likely of the three possibilities mentioned. But in view of the disproportionate number of non-pathogenic strains of *R. Solani* present in the soil of most fields, the net result through hybridization, if one may speculate, might be decreased, or at least not be perceptibly altered.

In conclusion, these results, and those reported by LeClerg (1), suggest that a crop of potatoes preceding sugar beets should not increase the danger to sugar beets from Rhizoctonia rootrot. One might also conclude from the evidence just submitted that a crop of sugar beets preceding potatoes should not increase the strains pathogenic to potato stems.

SUMMARY

1. Pathogenicity tests of 148 isolates of *Rhizoctonia Solani* obtained from sclerotia on potato tubers, from lesions on potato stems, and from basidiospores of the *Corticium* stage on potato stems, were made on large sugar beet roots under field conditions during 3 different years.

2. None of the isolates mentioned above showed any ability to attack the sugar beets under the conditions of the test.

3. As all plants inoculated with the 3 control isolates, of proven virulence from sugar beets, were killed within 20 days at average soil temperatures of 12 and 15° C., it is evident that this pathogen could cause severe damage to the sugar-beet crop in Alberta.

4. Although the results submitted suggest that a crop of potatoes preceding sugar beets should not increase the damage to the latter crop from Rhizoctonia rootrot, it still remains unproven whether or not strains pathogenic only to sugar beets might be harbored or even increased by a crop of potatoes.

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A STUDY OF THE NUTRITIONAL VALUE OF WHEAT GERM PRODUCTS FOR SWINE[1]

E. W. Crampton[2]
Macdonald College, Quebec

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Wheat germ is known to be a rich source of several nutritionally essential substances including the fat soluble vitamin E and certain of the fractions of the vitamin B complex. That the de-fatted germ contains as well some substance or substances which stimulate growth rate is suspected from the results of biological tests with laboratory animals.

Whether or not any fraction of wheat germ can be expected to improve standard rations for swine is not known, but in view of evidence that vitamin deficiency other than of A and D may be one causal factor in certain cases of poor growth and lack of thrift in growing pigs, a study of the nutritional value of this wheat by-product was undertaken.

This study consisted of two parts: the first dealt with the possible effect of supplements of wheat germ products to the sow ration on the growth of nursing pigs; the second dealt with the effects on the growth of market pigs, the efficiency of their utilization of feed, and the excellence of the bacon carcasses produced.[3]

PART 1. EFFECTS ON NURSING PIGS

Methods—Part 1

For Part I, 8 Yorkshire sows bred to farrow during January 1940, were grouped into 4 pairs, according to expected farrowing dates. Beginning 3 weeks prior to expected farrowing of the last pair, these sows were penned individually and detailed records of their feed consumption begun. It was impossible in this test to arrange for the feeding of the supplements earlier in pregnancy. Actually the two sows of Group II received their wheat germ supplement for 1 week prior to farrowing, those of Group III for 2 weeks, while one of those of Group IV received hers for 2, and the other for 3 weeks.

Excepting for the wheat germ supplements the rations of all 8 sows were identical as to composition. The meal mixtures consisted of 55% No. 2 feed barley, 30% No. 1 recleaned screenings, and 15% of a mixed protein-mineral supplement made up as follows: 44% meat meal, 15% fish meal, 20% linseed oilmeal, 10% bone char, 5% ground limestone, 5% salt (iodized at 1.7 oz. per 100 lb. salt), 1% ferric oxide.

To prepare the rations for feeding, the dry meal allowance for each sow was measured into her feed trough and the water allowance (roughly 3 times the weight of the meal) poured over it. Feeding was done 3 times per day in amounts readily eaten by the sows.

[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Que., Canada. Journal Series No. 153.
[2] Associate Professor of Animal Nutrition, Macdonald College (McGill University), P.Q.
[3] The author is indebted to the Ogilvie Flour Mills Co. Ltd., Montreal, for supplies of the wheat germ products used and for part financial assistance in this study.

In addition to the meal ration each sow was fed individually once daily 1 tablespoonful of cod liver oil (1800 I.U. "A" and 400 I.U. "D" per gram) and 1 tablespoonful of a solution containing 1 ounce of potassium iodide in a gallon of water.

The wheat germ supplements were fed as follows:

Group I, Sows No. 127 and 147—check lot.

Group II, Sows No. 124 and 150—de-fatted germ at level of 3% of dry meal ration.

Group III, Sows No. 134 and 149—de-fatted germ at 3% of dry meal plus $\frac{1}{4}$ oz. germ oil per sow daily.

Group IV, Sows No. 130 and 143—$\frac{1}{2}$ oz. germ oil per sow daily.

The wheat germ fractions were supplied by the Ogilvie Flour Mills Limited. The de-fatted germ is the product known commercially as VioBin and the oil as Rex Wheat Germ Oil.

The pigs of each litter were weaned at an age of 56 days. During the nursing period the young pigs were permitted to feed from their mothers' troughs at will. All male pigs of the litters were castrated at 4 weeks of age.

A summary of the results of Part I is given in Table 1.

TABLE 1.—SUMMARY OF FARROWING DATA AND GAINS OF NURSING PIGS

Treatment	Sow No.	Days on supplement previous to farrowing	Pigs born	Birth weight (all pigs)	Pigs weaned	Birth weight of pigs weaned	Weaning weight	Gain per pig during nursing period (56 days)
				lb.		lb.	lb.	lb.
Group I—Check	127	0	9	2.52	7	2.49	26.8	24.3
	147	0	10	2.09	5			
Group II—De-fatted Germ (VioBin)	150	7	12	2.47	8	2.60	29.4	26.8
	124	8	13	2.41	7			
Group III—De-fatted Germ plus Wheat Germ Oil	134	13	13	2.55	11	2.59	28.2	25.6
	149	14	8	2.52	7			
Group IV—Wheat Germ Oil	130	16	11	2.84	9	2.87	29.8	26.9
	143	23	12	2.64	11			

Discussion—Part I

As would be expected there were noticeable differences between the litters from the first, not all of which were due to feed. For example, sow 150 lay on and killed 4 of her litter when they were a week old. This occurred during a cold spell (20° below zero) when young pigs frequently pile up in the sow's bed when she leaves it, and are subsequently trapped when she lies down again. This reduction in her litter presumably would make available more feed to the remainder. Sow 124 farrowed 13 pigs, 4 of which were born dead. Thus both sows on the defatted germ nursed

considerably smaller litters than they originally produced. The same applies to sow 147 whose pigs at birth were rather weak; 3 of this litter died within a few hours. The other losses during the nursing period were scattered as to age and represented typical conditions of pig raising.

Casual examination of the data of Table 1 might lead one to conclude that the feeding of wheat germ fractions resulted in the birth of larger pigs and in heavier pigs at weaning. This interpretation of the data must be made with reservations, however, and for the following reasons. Differences in birth weight of pigs are known to be affected by factors other than or in addition to the food of the pregnant sow; it seems unlikely that the feeding of wheat germ products for 2 weeks previous to farrowing could be expected to be responsible for the difference between a litter of 10 in Group I averaging 2.09 pounds per pig and a litter of 11 in Group IV averaging 2.84 pounds per pig. Furthermore, pigs from sow 127 (Group I) averaged 2.52 pounds each, which was heavier than the pigs of either litter in Group II, and approximately the same as both litters in Group III.

It is possible by statistical methods to learn what proportion of total variability in the birth weights observed is chargeable to certain factors. Specifically the variance may be partitioned into that traceable to the 4 treatments, that due to difference of sows on the same treatment, and that within each litter independent of sow or treatment.

Table 2.—Analysis of variance of birth weights (all pigs born)

Variations due to	D/F	$S(x - \bar{x})^2$	σ^2 (Variance)
All causes	87	39.2043	0.4506
Between sows	7	20.9993	2.9999
Between treatments	3	4.3000	1.4333
Between sows on same treatment	4	16.6993	4.1748
Within litters	80	18.2050	.2276

Of the total variance in the birth weights of the 88 pigs farrowed, about 11% appears to be caused by differences in the rations fed to the pairs of sows; 43% to differences between litters from sows on the same rations; and 46% to differences in individuality of pigs within the same litter.

Concerning the variance due to differences between litters from sows on the same ration, it is interesting to note that Lush (Animal Breeding Plans, Collegiate Press, 1937, p. 81) reports data indicating that number of pigs per litter, year farrowed, and length of gestation period, may be expected to account for about one-third of this 43%. It is because of the extent to which birth weight can be influenced by factors other than the kind of feed eaten by the pregnant sow that the significance of ration supplement on birth weight of pigs is often difficult to demonstrate.

In this test, the sows receiving the wheat germ oil farrowed larger pigs than any of the other six. However, this increase in birth weight of pigs from the sows receiving only the germ oil supplement was not as great as might occur from differences between sows on the same feed. Thus generalizations cannot be made from the data of this test as to any positive effect of these sow ration supplements on size of pig born.

From Table 2 it will be noted that there was considerable variability between pigs of the same litter. Statistical examination of these data reveal that this was as large in litters from sows of one group as from another, and it must, therefore, be concluded that the supplements were without effect in this connection.

The same statistical analysis may be applied to the weights of the pigs at weaning time, and yields data shown in Table 3.

TABLE 3.—ANALYSIS OF VARIANCE OF WEANING WEIGHT OF PIGS

Variations due to	D/F	$S(x - \bar{x})^2$	σ^2 (Variance)
All causes	64	2027.43	31.68
Between sows	7	461.70	65.96
Between treatments	3	81.80	27.27
Between sows on same treatment	4	379.90	95.00
Within litters	57	1565.73	27.46

As with birth weight, the largest factor in the variation in weaning weights of the pigs has been the individuality of the sows. Thus we are unable to demonstrate any significant effect of the wheat germ supplements on the growth of the pigs during the nursing period.

From Table 1, however, it is seen that the pigs on the wheat germ supplements were larger than those of the check lot. This is not incompatible with the above conclusion in view of a positive and statistically highly significant ($P = 0.01$) correlation of $+0.51$ between size of pig at birth and its size at weaning time. This is but another way of saying that for pigs which were weaned, the larger pigs at the start were also the larger at weaning time. Quantitatively this is measured by a regression of weaning weight on birth weight of $b = 7.8598$ pounds. Thus for each 1 pound increase in birth weight we expect 7.86 pounds increase in weaning weight.

This regression may be used to adjust the observed weaning weights for the differences in initial weights. The differences between the adjusted average weaning weights will then be uncomplicated by the effects of the birth weights. Thus we have:

	Observed weaning weight	Adjusted weaning weight
Check	26.8 lb.	28.1 lb.
Group II	29.4	29.9
Group III	28.2	28.8
Group IV	29.8	28.2

None of the differences between these adjusted means are significant, which is interpreted that the supplements fed to the nursing sows have had no effect on the rate of gain of the sucking pigs.

PART II. EFFECTS ON MARKET PIGS

Methods—Part II

In order to study the possible effect of these same wheat germ products on the growth of market pigs and on the carcasses produced, 64 of the 65 pigs weaned by these 8 sows were re-allotted to feeding groups in such a way that the pigs from each "sow group" were as equally as possible (and at random) distributed between the 4 feeding groups. This plan was used to equalize any effect of previous treatment or hereditary influence on the progress of the pigs. Since not all sows weaned 8 pigs, it was necessary to adjust the allotment by distributing surplus pigs of sows 134, 130, and 143 to the litters of the other sows. Tables of random numbers were used in making all allotments.

All pigs were individually penned and fed from weaning time to a market weight of about 200 pounds. From the start of the test to a weight of 100 pounds the pigs were fed 3 times a day using a mixture consisting of 85% No. 2 feed barley, and 15% of mixed protein-mineral supplement made up as follows: 20% meat meal, 15% fish meal, 35% linseed oil meal, 10% brewers dried yeast, 10% bone char, 5% limestone, and 5% salt.

The dry meal allowance for each pig was placed in its feed trough and the water allowance (about 3 times the weight of the dry feed) poured over it. Once daily during this period each pig received 15 cc. of cod liver oil. As each pig reached a weight of 100 pounds, its ration was changed to consist of 90% barley and 10% protein mineral supplement. During this period feeding was done twice daily. All pigs were fed to the limit of their appetites throughout the test.

In addition to the regular rations above described, wheat germ supplements were incorporated in the meal rations as follows:

Lot I—16 pigs—check lot.

Lot II—16 pigs—de-fatted wheat germ at 3% of meal ration.

Lot III—16 pigs—de-fatted germ at 3% plus wheat germ oil at 0.5% of meal ration.

Lot IV—16 pigs—wheat germ oil at 0.5% of meal ration.

Results—Part II

The results of Part II of this test are presented in three sections,—(1) the growing period (pigs to 100 pounds), (2) the total feeding period, and (3) the carcass data.

The Growing Period

The criteria of ration differences during this period were gains in the live weight of the pigs, their feed consumption, and the appearance of the animals as to health, thrift, and bloom. The first two criteria are matters of statistical record and lend themselves to analysis according to recognized procedures (analysis of variance and co-variance). The results of such analyses are given in Tables 4 and 5.

TABLE 4.—AVERAGE GAINS IN LIVE WEIGHT AND OF FEED CONSUMPTION OF PIGS FROM WEANING TO 110 POUNDS

Feeding group	Average daily gain (observed)	Average daily feed (observed)	Daily gain adjusted to average feed intake and average initial weight
	lb.	lb.	lb.
Lot I—Check	1.05	3.60	1.06
Lot II—De-fatted Germ	1.21	3.98	1.13
Lot III—De-fatted Germ plus Oil	1.10	3.49	1.13
Lot IV—Germ Oil	1.06	3.54	1.08

Standard deviation of adjusted gains = ± 0.0598 lb.
Difference between adjusted mean gains which may be expected ($P = 0.05$) from causes other than treatment:

$$\left\{\frac{0.0598}{\sqrt{16}} \times \sqrt{2} \times 1.95996\right\} = 0.0414 \text{ lb.}$$

As measured by the increased rates of gains in live weight made during the growth period following weaning, it seems evident that the two rations containing the de-fatted wheat germ (VioBin) have given statistically significant effects. Wheat germ oil additions, however, have not shown this effect, the difference in gains between the check lot and Lot IV being less than the difference which may be expected from chance grouping and individual pig variation.

This interpretation of the gain data is borne out by the observed difference in the bloom and condition of the pigs. Up to this point the pigs of Lot II especially (de-fatted germ) could be identified from others by the whiteness of their skin and sleek appearance of the hair coat.

That this condition was not an effect of previous treatment is indicated by averaging the adjusted gains according to the sow group from which the pigs came. Thus we find:

	Average Gain of Pigs
From sow group I (Check)	1.11 lb.
From sow group II (De-fatted Germ)	1.08 "
From sow group III (De-fatted Germ plus Oil)	1.09 "
From sow group IV (Oil)	1.13 "

Here the pigs from the sows receiving "oil" showed the greatest gains though none of the differences were statistically significant at odds of 5%.

The Total Feeding Period

The live hog data for the total feeding were analysed according to the same procedures as for the growing period with results shown in Table 5.

It appears from this data that the pigs on the VioBin (Lot II) and those on VioBin plus oil (Lot III) maintained the advantage over the check and the oil groups shown during the early part of the feeding period. The very obvious differences in bloom noted with the pigs on VioBin during the first month after weaning were less evident at the close of the finishing period.

Table 5.—Average gains in live weight and daily feed consumption of pigs from weaning to market weight of 200 lb.

Feeding group	Average daily gain (observed)	Average daily feed (observed)	Daily gain adjusted to average feed intake and average initial weight
	lb.	lb.	lb.
Check	1.33	4.97	1.34
De-fatted Germ	1.48	5.39	1.40
De-fatted Germ plus Oil	1.41	4.92	1.43
Oil	1.32	4.82	1.38

Standard deviation of adjusted gains = ± 0.0748.
Differences between adjusted mean gains expected ($P = 0.05$) from causes other than treatment:

$$\left\{\frac{0.0748}{\sqrt{16}} \times \sqrt{2} \times 1.95996\right\} = 0.0518 \text{ lbs.}$$

The chief effect of the de-fatted germ (Lot II) appeared to be an increased feed intake which undoubtedly was responsible for the increased gains noted. This effect was noted in both lots receiving the VioBin (Lots II and III) but not in Lot IV which received the oil only. It would seem, therefore, that whatever factor was responsible for this increase in rate of gain was in the fat-free part of the wheat germ. The extent of the effect is indicated by the fact that whereas the check lot pigs and the oil fed pigs required 126 days of feeding to reach market weight, the pigs of Lot II reached 200 pounds in 112 days and those of Lot III in 121 days. Why the lot fed VioBin plus oil did more poorly than the VioBin fed lot is not explainable from the data of this test.

Carcass Data

The carcasses of all pigs were individually examined and scored as to excellence according to the standards employed by the Federal Department of Agriculture in connection with the tests for the Advanced Registry for Swine. From the standpoint of this study it was desirable to know whether or not the feed supplements had any effects on those features of the carcass which might influence its market value, such as carcass score, length of side, rail grade, size of eye of lean, percentage lean in the rasher, or firmness of fat.

A summary of the lot averages in respect to these items is shown in Table 6.

Table 6.—Carcass data—averages by lots

Item	Lot I Check	Lot II VioBin	Lot III VioBin+Oil	Lot IV Oil
Carcass Score (%)	79	79	78	79
Carcass Length (in.)	30.4	30.3	30.5	30.3
Eye of Lean (sq. in.)	5.6	5.5	5.4	5.6
Lean in Rasher (%)	46	46	44	46
Firmness of Fat	Firm	Firm	Firm	Firm
Rail grade, A's	9	10	8	10
B's	6	6	7	5
C's	0	0	1	1

Concerning the carcass excellence it is evident that no marked differences occurred which were traceable to wheat germ supplements. The distribution of the carcasses among the grades is quite typical of the run of hogs from this station. Grade A carcasses receive a bonus of $1.00 per hog while Grade C hogs usually are cut 50 cents from the B Grade, which is the standard for price quotation. The one C hog in Lot IV proved to be a ridgling (an hereditary defect) and the C hog in Lot III cut out a short, thick carcass.

DISCUSSION

It has been impossible to demonstrate a positive effect of any of the wheat germ supplements on birth weight of pigs due largely to the considerable variation in this respect between sows on identical rations. Nor was there any measurable effect during the nursing period, the difference in weaning weight being accounted for by the positive correlation between birth weight and weaning weight.

Once weaned, however, the inclusion of VioBin in the market pig ration had marked effect both on the growth rate and on the "bloom" of the pigs. The increased growth rate was associated with an increased food intake. The efficiency of the ration was also somewhat increased over the check or oil fed lots.

One of the frequent results of the addition of vitamin B^1 to diets is an increased food intake. The rations of the market pigs in this test were fortified with yeast, however, with a view to providing the known "B complex". Recent work on rats by McHenry (personal communications) suggests that wheat germ may contain a factor, as yet unidentified, which facilitates either the synthesis of fat from carbohydrates or transportation in the animal body of such newly synthesized fat.

In a recently completed test with hogs at Macdonald College (unpublished) Durum wheat (as 85% of ration) has given more rapid gains than comparative lots in which barley was fed. Furthermore, the carcasses from these wheat fed hogs were higher in percentage fat for pigs of equal market weight. The same situation was found with high grade screenings which was largely broken wheat. Feed wheat, which represents a damaged product (often by freezing), gave results similar to barley in that no tendency for increased fat deposition was noted. In previous tests corn fed hogs gave carcass results somewhat similar to the Durum wheat.

It would seem worth while to investigate further the possibility that in undamaged germ from wheat and perhaps also from corn there may be a factor (perhaps belonging to the B vitamin family, since the result was obtained with de-fatted wheat germ) which has an effect on the production of depot fat from dietary carbohydrates.

In connection with Lot III, fed both "VioBin" and "oil", the advantageous effects of the VioBin appeared in lesser degree. The marked bloom on the pigs in this lot for the early part of the feeding period was lacking and the growth rate was less. This lot stood intermediate between the check lot and the VioBin fed group in rate of gain. Feed consumption, however, was below the check lot throughout the feeding period, and was probably the cause of the slower gains.

SUMMARY

1. The addition to the ration of pregnant sows for a period of 2 to 3 weeks previous to farrowing of wheat germ oil at a rate of ½ ounce per day or of de-fatted germ at the rate of 3% of the dry feed did not appear to have any effect on the birth weight of pigs farrowed.

2. Supplements to the nursing sow ration of VioBin as 3% of the dry meal fed or of the extracted oil at ½ ounce per sow per day did not result in measurable differences between the check group and comparative litters in the health or gains of the pigs during the nursing period of 56 days.

3. The inclusion of de-fatted wheat germ (VioBin) as 3% of a ration of market pigs (consisting of barley supplemented with a standard protein-mineral supplement and especially fortified with yeast and cod liver oil) resulted in considerable increase (8.5%) in feed consumption and in more rapid (10%) gains in live weight. Since there was but slight increase in gain per unit of feed eaten, it appears that the major effect of the VioBin was in stimulating appetite. Coincidental with the increase in growth rate was a noticeable "bloom" on the pigs especially during the early part of the feeding period.

4. The addition to the diets of such market pigs of wheat germ oil at ½% of the meal ration failed to result in any increase in growth or to otherwise distinguish these pigs from those of the check lot.

5. Neither the VioBin nor the oil supplements in any way affected the excellence or character of the bacon carcasses cut from the hogs on this test.

A NOTE ON THE EFFECT OF MULTIPLE BIRTHS ON THE SEX RATIO IN SHEEP[1]

K. RASMUSSEN[2]

Dominion Experimental Station, Lethbridge, Alberta

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Sex ratios have been the object of considerable interest to numerous investigators. Numerous reports have been published regarding this subject and it might appear to be unnecessary to discuss the matter further. However, in analyzing the sheep breeding records at the Dominion Experimental Station for another purpose a peculiarity of sex ratios in this flock was apparent and seemed of sufficient interest to justify this note. The sex ratio for the flock closely approaches that normally accepted for sheep but a distinct difference was observed in the sex ratios for singles and twins of like sex.

The data were obtained from the breeding and lambing records of the Station flock for the years 1934 to 1940 inclusive, and comprise 3711 lambs in 6 groups. The data are summarized in Table 1.

TABLE 1.—DISTRIBUTION, BY TYPE OF BIRTH, OF LAMBS BORN IN VARIOUS BREED GROUPS 1934–40

Type of Birth	Breed Groups						Total	
	New Zealand Corriedale	Canadian Corriedale	Purebred Rambouillet	Grade Rambouillet mated to Rambouillet Sires	Grade Rambouillet mated to Corriedale Sires	F_1 mated to Corriedale Sires	Male	Female
Single males	71	240	235	139	107	71	863	
Single females	62	228	201	134	99	82		806
Twin M M	6	156	62	104	90	20	438	
Twin F F	18	184	70	124	106	34		536
Twin M (Born with F)	9	208	77	115	89	36	534	
Twin F (Born with M)	9	208	77	115	89	36		534
Totals	175	1224	722	731	580	279	1835	1876
							3711	

The data comprise 3711 twins and singles and in addition there were 42 triplets not included in the table. The triplets were evenly divided between males and females and of the twins and singles 1835 were males and 1876 were females. This yields a sex ratio of 49.4% males to 50.6% females which agrees closely with the average for previous reports.

[1] Contribution from the Animal Husbandry Division, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Assistant Superintendent.

However, a closer analysis of the data shows that there is a distinct difference in the ratio of lambs born as singles and those born as twins of like sex. The singles had 51.7% males and 48.3% females, whereas for the twins of like sex there were 45.0% males and 55.0% females.

The preponderance of females among twins of like sex is consistent for all the groups, and the total shows a significant deviation from the sex ratio of all lambs as well as from the 50 : 50 ratio. For the individual groups the deviation from expected is not significant except for the New Zealand Corriedales. A summation of chi-squares for each group yields a value of 13.15 for 5 degrees of freedom, a value between the 5% and 1% point. If the totals only are considered, the chi-square value is 7.59, also highly significant. Thus the evidence favours the view that some factor is at work to cause a surplus of twin females or a deficiency of twin males to be born.

The latter seems to be the more probable in view of the number of twin females in relation to twins of mixed sexes. No definite cause can be ascribed for the deficiency of twin males of like sex, although the surplus of single males may suggest that intrauterine mortality of one of a set of twin males may occur more frequently than in female twins or in twins of unlike sex. This would then cause some single males to be born from what were twin male conceptions and would explain the situation that has been observed.

Further data are required before definite conclusions can be drawn, but the number of lambs involved and the consistency of the data appear to overrule the chance factor in deviations of sex ratio.

WHEAT SEED TESTING FROM THE PATHOLOGICAL STANDPOINT WITH SPECIAL REFERENCE TO EMBRYO EXPOSURE[1]

R. C. Russell[2] and R. J. Ledingham[3]
Dominion Laboratory of Plant Pathology, Saskatoon, Sask.

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In 1935, Simmonds and Mead (9) published an article on the development of better methods for the examination of seed wheat from the plant pathological standpoint. The present work was undertaken with the object of testing and further improving the technique described by them. The desirability of developing methods of testing seeds for seed borne diseases which would be economically practicable as well as scientifically sound was kept in mind.

It should be recognized that the factors mentioned below greatly affect the value of seed wheat. It is most desirable that all seed should be relatively free from parasitic fungi and bacteria. Seeds shrivelled by drought or rust lack sufficient food reserves, and produce seedlings which are unable to stand up well under adverse conditions during the early stages of growth. Frost, which occurs while the grain is maturing, may injure the embryo and also reduce the food reserves. Mechanical injury to the seed coats exposes seeds to attack by both parasitic and saprophytic soil micro-organisms as well as to injury from fungicides. It would be desirable then if samples of grain could be subjected to certain routine tests, by means of which their suitability for seed could be reliably determined.

Besides testing for the presence of seed-borne parasites, it is important to examine seed samples for other defects. The value of grain for seed purposes may be considerably reduced by the action of such factors as frost, rust, or excessive moisture causing premature sprouting. Mead (6) has shown that seedlings from such seed are more susceptible to infection from *Helminthosporium sativum* P.K. & B. Also, seed may be cracked or broken by ordinary threshing and cleaning machinery. As early as 1872, Nobbe (7) recognized the fact that machine-threshed seed was more injured by copper sulphate than was hand-threshed seed, because damage done to the seed coats by the machine allowed the poison to penetrate to the embryo. Hurd (2) conducted an extensive series of investigations into the effect of seed coat injuries on the damage caused by moulds and fungicides. She found that wheat seeds with sound coats were not harmed by moulds or fungicides under ordinary conditions while those with broken seed coats were often severely damaged. Such breaks over the embryo accounted for severe injury from copper sulphate and formaldehyde, while breaks over the endosperm admitted saprophytic fungi which used up the food supply in the seeds and thus prevented the normal development of the seedlings. Machacek and Greaney (4, 5) found that more infection, from artificial inoculations with *Fusarium culmorum* (W. G. Sm.) Sacc.,

[1] Contribution No. 641 from the Division of Botany and Plant Pathology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.
[2] Plant Pathologist.
[3] Graduate Assistant.

occurred in seedlings from cereal seed of which the pericarp and testa had been broken by mechanical means. Experiments reported by Noll (8) indicate that certain species of Penicillium may feed upon the endosperm and also attack the developing seedlings when admitted into the seed by fractures in the pericarp and testa. Alberts (1) showed that corn with cracks in the seed coats over the embryo is less valuable for seed than similar grain with sound coats. In the studies described below considerable attention was paid to the significance of cracks or breaks in the pericarp and testa which expose the embryo.

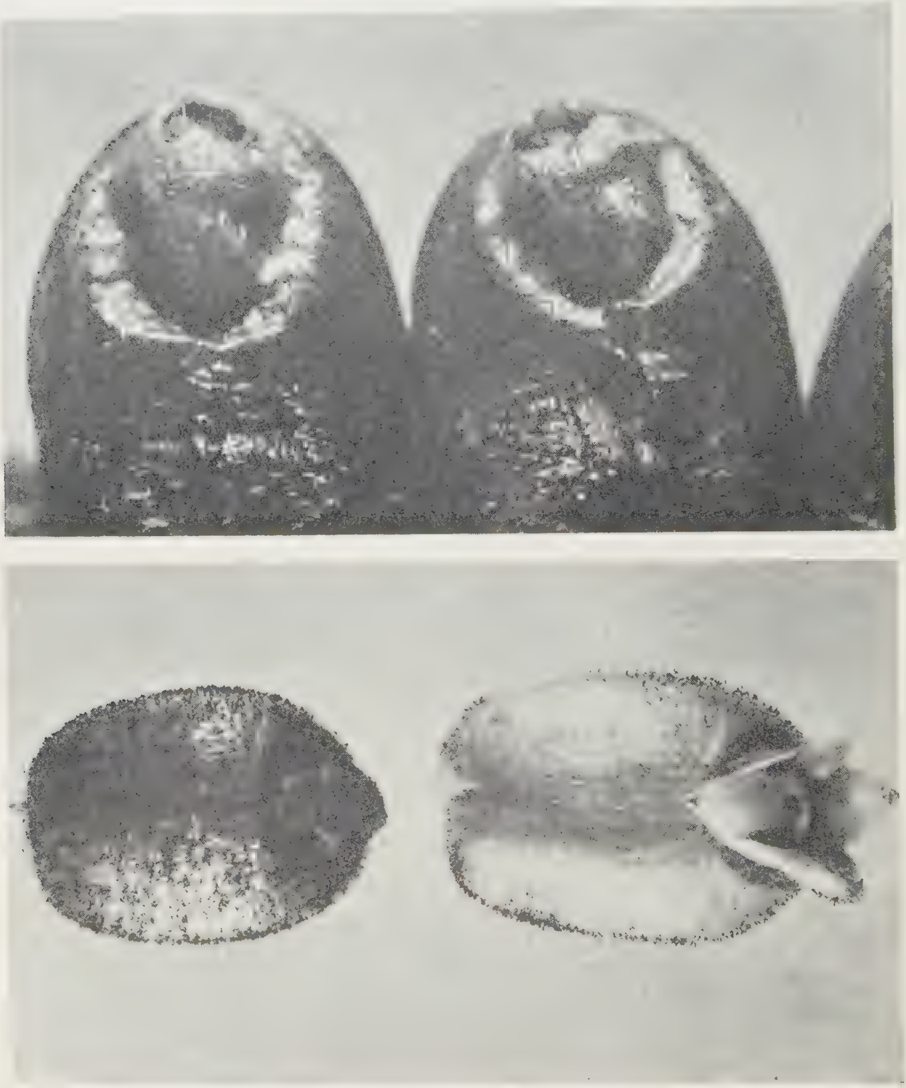

FIGURE 1. Top: Wheat grains showing breaks in the pericarp and testa at the tips of the grains; ×16. The embryos are exposed to the direct action of fungi and fungicides. Bottom: Wheat grains, selected from an incubation test, covered with the conidiophores and conidia of *H. sativum* arising from seed-borne infection; ×9.

MATERIALS AND METHODS

Several hundred farmers' samples of wheat seed were obtained, partly through the Dominion Government Plant Production Service Laboratory at Saskatoon, and partly by direct contact with farmers. These samples came from all parts of Saskatchewan and probably are representative of the wheat seed used by the better class of farmers throughout the province.

All of these samples were subjected to the following tests.

(1) *Visual Examination.* Each sample was examined in good light and a record kept of its condition with respect to colour and plumpness. The presence of ergot bodies or bunt balls and any other indications of parasitic disease, such as smudge, black-point, and scab were noted when present. The presence of piebald and green or otherwise discoloured kernels was recorded even though they were not regarded as indicative of parasitic troubles.

(2) *Examination for Exposed Embryos.* A portion of each sample was placed in a glass tube of small bore and examined under a wide field binocular microscope. The approximate percentage of grains showing cracks or breaks in the pericarp and testa over the embryo (Figure 1, top) was recorded.

(3) *Centrifuge Test.* A portion of each sample, weighing 40 grams, was placed in an Erlenmeyer flask with 60 cc. of water. After the flask had been corked and the grain and water had been shaken vigorously for 4 minutes, the water was poured off and four 12-cc. portions were centrifuged for 4 minutes. All but about $\frac{1}{2}$ cc. of the water was then poured off and 4 drops of the remaining water and sediment were examined under a microscope. A record was kept of the presence of fungus spores, particularly those of bunt, which had been washed from the surface of the grain. If bunt spores were present but scarce, it was recorded as a "trace minus". If, on the average, there was 1 spore present for every microscopic field examined, it was recorded as a "trace". A "trace plus" indicates 2 or 3 spores per field, while "slight" indicates from 4 to 10 spores per field. An average of 10 to 50 spores on each field was recorded as "moderate", and anything more than that as "heavy". One spore per microscopic field is equivalent to about 150 spores per kernel.

(4) *Incubation Test.* One hundred kernels of each sample were placed without any previous treatment on moist filter paper in 4 Petri dishes. These were kept in an incubator at a temperature of 24.5° C. for 4 days. At the end of that period the number and kinds of fungus colonies present on the kernels (Figure 1, bottom) were recorded.

Certain of the samples were investigated still further in germination tests in pots in the greenhouse and in germination, yield, and bunt tests, conducted in the field. These were undertaken as a check upon the practical value of the above mentioned tests.

TESTS AND EXPERIMENTS

Routine Seed Tests

In Table 1 is shown a summary of the results obtained in the general tests. The data are arranged in 4 groups according to the soil zone from which the samples came.

TABLE 1.—SUMMARIZED RESULTS OF THE GENERAL TESTS ARRANGED ACCORDING TO SOIL ZONES

Saskatchewan soil zones	Visual examination				Microscopic examination				
	Samples showing smudge	Kernels showing smudge	Samples showing piebald	Kernels showing piebald	Kernels with exposed embryos	Samples showing bunt	Average number of bunt spores per microscopic field	*Kernels showing *H. sativum*	*Kernels showing *Alternaria* spp.
	%	%	%	%	%	%		%	%
1. Brown (33 samples)	15.0	0.105	3	0.045	26.4	27	0.072	0.21	5.2
2. Dark brown (58 samples)	17.0	0.235	12	0.260	28.2	52	0.197	0.34	11.6
3. Black (66 samples)	36.5	0.562	53	7.300	29.1	21	0.069	1.71	33.7
4. Grey (24 samples)	46.0	0.740	83	15.495	19.0	25	0.077	1.79	27.0

* The data concerning *H. sativum* and *Alternaria* spp. are derived from the incubation tests.

The figures indicate that there is a correlation between the environmental conditions under which the wheat was grown and the condition of the seed grain. According to Joel *et al.* (3) "over large areas and in a broad way, the effects of climate and natural vegetation are the dominant factors in soil development". The 4 soil zones of Saskatchewan may be briefly described as follows: zone 1 consists of the brown soils on which is found the short grass prairie of southwestern Saskatchewan; zone 2 is made up of the dark brown soils supporting the intermediate prairie which lies between the short grass prairie and the tall grass "Park" region on the black soils of zone 3; zone 4 contains the grey soils of the wooded region bordering the rocky Laurentian Plateau of northern Saskatchewan. The native floras of these different zones vary to a considerable extent, so it was thought that the wheat samples produced on them might vary in quality, fungus infection, and other respects. This appeared to be the case.

Starting with zone 1 there is a distinct and consistent rise in the amount of smudge with each succeeding zone. The same is true of the percentage of piebald kernels. In the case of *H. sativum* there was a consistent increase for the first 3 zones, but zone 4 showed very little more than zone 3. Bunt was most prevalent in zone 2, where over 50% of the samples carried more or less smut. However, the amount of bunt per sample was usually very small in all of the zones. The amount of embryo exposure was about the same in all zones except zone 4 where it appeared to be distinctly less.

The same data were arranged and summarized according to the varieties of wheat represented (Table 2). Distinct correlations cannot be seen as readily as in Table 1, but the figures suggest that Marquis and Thatcher may be less likely to become severely cracked than are Apex, Regent and Renown. Regent appears to be less susceptible to bunt but more susceptible to *H. sativum* than are the other varieties. Also a relatively high percentage of Regent seed carried *Alternaria* spp.

TABLE 2.—SUMMARIZED RESULTS OF THE GENERAL TESTS ARRANGED ACCORDING TO VARIETY

Variety	Visual examination: Samples showing smudge	Kernels showing smudge	Samples showing piebald	Kernels showing piebald	Microscopic examination: Kernels with exposed embryos	Samples showing bunt	Average number of bunt spores per micro-scopic field	*Kernels showing *H. sativum*	*Kernels showing *Alternaria* spp.
	%	%	%	%	%	%		%	%
Apex (58 samples)	27.6	0.57	24.1	3.59	28.0	36.2	0.108	0.86	15.6
Marquis (17 samples)	41.2	0.53	29.4	2.29	22.1	41.2	0.103	0.24	14.4
Regent (52 samples)	23.1	0.42	42.3	9.94	30.1	17.3	0.048	1.40	29.2
Renown (17 samples)	17.6	0.41	58.8	7.00	35.5	41.2	0.103	0.76	22.1
Thatcher (22 samples)	27.3	0.45	45.5	3.73	19.4	45.5	0.136	0.36	16.8

*The data concerning *H. sativum* and *Alternaria* spp. were derived from the incubation tests.

Field Test for Bunt

This test was undertaken with the object of finding out the amount of bunt infection which would develop under field conditions from a given amount of bunt spores on the seed as revealed by the centrifuge test. A number of rows were sown with artificially inoculated seed to obtain additional information.

Seed from 17 samples which had been examined by the centrifuge method were sown in rod rows in the field. There were 4 replications of each as well as 16 rows sown with artificially inoculated seed. Two lots of inoculated seed were prepared. In one case 1 part of bunt spores, by weight, was mixed with 64 parts of seed. In the other lot 1 part of bunt spores was mixed with 320 times its weight of wheat seed. At harvest time 300 heads from each row were examined for bunt. The results obtained are shown in Table 3.

The results obtained show that bunt developed readily, under the conditions prevailing in this test, when bunt spores were plentiful on the seed, as in the case of the artificially inoculated rows. Moreover, a slight amount in one sample of Reward seed resulted in an infection of 2.2% while a moderate spore load on the other Reward sample produced 5.6% of bunted heads in the standing crop. Six samples bearing a trace of bunt produced a trace of bunt in 1200 heads and the other 5 did not.

Greenhouse Tests Showing the Effects of Embryo Exposure

From among the many wheat samples subjected to the general tests, 3 samples of Regent wheat were selected for further germination tests. They all came from the same general area in Saskatchewan and all germinated well (94 to 97%). The percentage of kernels showing embryo exposure, however, was 15, 50 and 85%, respectively, for the 3 different samples.

Table 3.—Field test for bunt, showing the percentage of infection resulting from various amounts of bunt spores on the original seed

Variety	Spore load according to centrifuge test		Percentage of heads showing bunt in mature crop
	Bunt in seed sample	Spores per microscopic field	
			%
Apex	Nil	0	0.00
	Trace	1	0.17
	Trace	1	0.08
	Trace	1	0.00
Regent	Nil	0	0.00
	Trace	1	0.00
Reward	Nil	0	0.00
	Moderate	10 to 50	5.67
	Slight	4 to 10	2.25
Thatcher	Nil	0	0.00
	Trace	1	0.08
	Trace	1	0.00
	*Trace	1	0.08
Miscellaneous	Trace	1	0.00
	Trace	1	0.08
	Trace	1	0.00
	Trace	1	0.17
Apex	1 : 320	1200 to 1600	4.00
	1 : 320	1200 to 1600	4.40
	1 : 64	6000 to 8000	12.70
	1 : 64	6000 to 8000	14.20
	Check	0	0.08

* This sample was partly Reward wheat.

These were subjected to seed treatment tests with formalin and with ceresan[1] and to a pathogenicity test with *H. sativum.* In each of these tests 600 seeds were taken from each sample and 300 were treated while the other 300 were sown as checks. They were sown in a screened mixture of 1 part sand to 5 of field soil. Fifty seeds were sown in each 6-inch flower pot at a depth of $1\frac{1}{2}$ inches, and the pots were arranged on the greenhouse bench in the form of a Latin square. After the test had run for a period of 10 days the seedlings were dug up and examined and placed in the following classes:

Normal: of average height and unblemished.

Delayed: emerged and unblemished but below normal height.

Distorted: emerged but below normal height and with somewhat distorted leaves.

Blighted: partially germinated, but not emerged, and also decidedly distorted and frequently bearing dark brown lesions.

Non-germinated: no signs of germination.

In the formalin test one-half of the seeds were soaked in a 1 to 320 solution of commercial formalin and water for 5 minutes, then drained, and

[1] In each case in this paper the word "ceresan" refers to the product sold as New Improved Ceresan.

covered with a towel for several hours before seeding. The check seed was soaked in tap water and spread out to dry in the same manner. The results of this test are shown in Table 4.

TABLE 4.—THE INFLUENCE OF EMBRYO EXPOSURE UPON INJURY FROM THE FORMALIN TREATMENT

Kernels showing exposed embryos	Treatment	Germination					
		Seedling classes				Seeds not germinated	Total emergence
		Normal	Delayed	Distorted	Blighted		
%							
15	Check	256	18	4	12	10	278
	Formalin	216	27	4	28	25	247
50	Check	239	16	6	16	23	261
	Formalin	183	26	10	47	34	219
85	Check	221	19	6	36	18	246
	Formalin	136	35	7	79	43	178

As may be seen from the data presented, there is a distinct correlation between the percentage of cracked kernels in each sample and the amount of injury from the treatment. The formalin treatment reduced both the normal germination and the total emergence in all 3 samples of wheat. The normal germination was reduced more than the total emergence. In other words more of the treated seeds produced seedlings that were below normal height.

In a similar test ceresan was used to treat the seed instead of formalin. In order to get a satisfactory distribution of the dust over the seed, talc was added to the ceresan. The mixture, consisting of 0.006 gm. of ceresan and 0.05 gm. of talc, was shaken in a closed flask with 300 wheat seeds. Talc alone was applied to the checks. After treatment the samples were placed in envelopes and left for 2 days before seeding. The results of this test are given in Table 5, and show that ceresan had a beneficial effect, as it increased both the normal germination and the total emergence in nearly every case.

TABLE 5.—THE INFLUENCE OF EMBRYO EXPOSURE UPON THE GERMINATION OF WHEAT SAMPLES TREATED WITH CERESAN

Kernels showing exposed embryos	Treatment	Germination					
		Seedling classes				Seeds not germinated	Total emergence
		Normal	Delayed	Distorted	Blighted		
%							
15	Check	230	34	5	22	9	269
	Ceresan	235	29	4	19	13	268
50	Check	222	24	12	23	19	258
	Ceresan	249	24	7	16	4	280
85	Check	195	38	8	41	17	241
	Ceresan	230	18	9	21	22	257

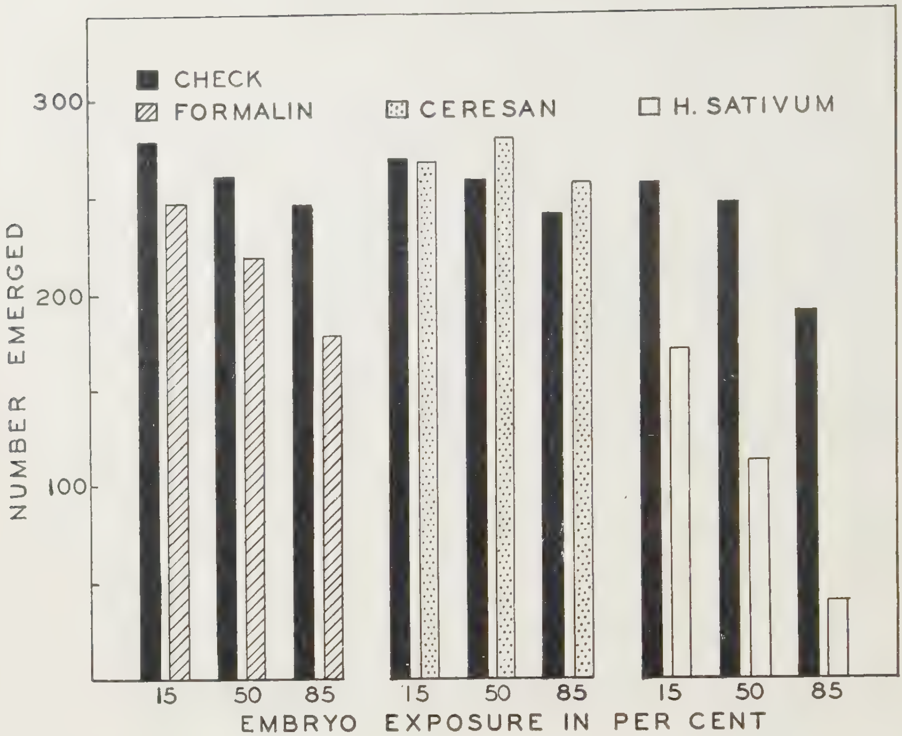

FIGURE 2. Influence of several treatments on the emergence of wheat seed samples having different percentages of embryo exposure.

These same 3 seed samples were subjected to a pathogenicity test with *H. sativum*. The seed was inoculated by the following method: spores from actively sporulating colonies of the fungus on potato dextrose agar in petri dishes were suspended in water and the seed was treated with $\frac{1}{10}$ of its own weight of the suspension and sown immediately. In other respects the test was conducted in the same manner as the formalin and ceresan tests. The results are shown in Table 6 and indicate that the

TABLE 6.—THE EFFECT OF EMBRYO EXPOSURE ON THE GERMINATION OF WHEAT SAMPLES INOCULATED WITH *H. sativum*

Kernels showing exposed embryos	Treatment	Germination					
		Seedling classes				Seeds not germinated	Total emergence
		Normal	Delayed	Distorted	Blighted		
%							
15	Check	225	32	0	18	25	257
	Inoculated	114	54	3	43	86	171
50	Check	227	13	6	16	40	246
	Inoculated	67	38	8	48	139	113
85	Check	157	24	10	35	74	191
	Inoculated	27	10	4	26	233	41

amount of injury varied with the percentage of kernels showing exposed embryos; the greater the amount of embryo exposure the greater was the injury from the fungus. They also show that the inoculation reduced the normal germination and the total emergence considerably.

The results of the 3 tests just described, presented graphically in Figure 2, indicate clearly the consistent decrease in total emergence with each increase in the amount of embryo exposure, in the case of the untreated checks. The same thing is true in the case of the seed which was treated with formalin or inoculated with *H. sativum*, the decreases being more pronounced. It also shows that the ceresan treatment, on the other hand, tended to improve slightly the emergence of the seed with the exposed embryos.

The influence of embryo exposure upon injury from various causes was still further tested with hand picked seed from a sample of Apex wheat produced at Indian Head. The seed was selected with the aid of a wide field binocular microscope. Kernels with sound pericarps and testas were picked out as checks. Those with slightly or moderately cracked seed coats were discarded and only those with badly exposed embryos were employed in the test. The sound and the badly cracked samples were subjected to the same pot tests as those described above with the 3 samples of Regent wheat. A summary of the results of all 3 tests is given in Table 7.

Table 7.—The influence of embryo exposure on the reaction of wheat to treatment with formalin, ceresan and *H. sativum*

Sample	Treatment	Germination: Seedling classes: Normal	Delayed	Distorted	Blighted	Seeds not germinated	Total emergence
Sound	Check	285	7	0	4	4	292
	Formalin	260	14	3	15	8	277
Cracked	Check	183	36	10	20	51	229
	Formalin	92	39	22	55	92	153
Sound	Check	268	10	7	10	5	285
	Ceresan	279	11	3	6	1	293
Cracked	Check	126	58	9	38	69	193
	Ceresan	173	37	17	20	53	227
Sound	Check	265	7	9	17	2	281
	H. sativum	173	32	24	62	9	229
Cracked	Check	145	36	11	37	75	192
	H. sativum	98	55	13	68	63	166

These indicate the same trends as those in Tables 4 to 6. It was expected that the differences between the results obtained from sound and badly cracked seed would be more pronounced when the selected seed was used. This proved to be the case in the formalin and ceresan tests but not in the *H. sativum* test (Figure 3). The injury from the formalin treatment

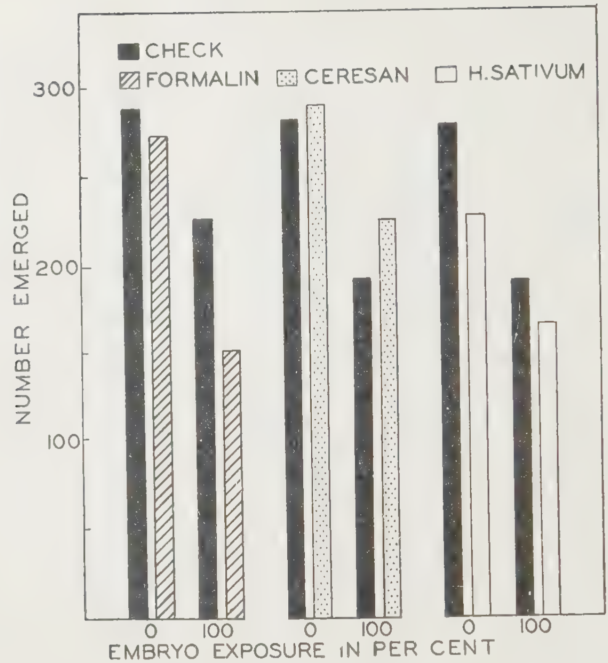

FIGURE 3. Influence of several treatments on the emergence of sound wheat seed and of seed, selected from the same source, having exposed embryos.

was much more pronounced and so were the beneficial effects of the mercuric dust treatment. Just why the exposure of the embryos did not lead to more infection from the fungus in this test is not clear.

Field Tests Showing the Effects of Embryo Exposure

The Effects of Seed Treatments on Different Samples of Apex Wheat

The seed treatments chosen for this test were formalin, ceresan, and Lunasan. Three samples of Apex wheat were used. The first, which was used as a check, came from Melfort and was a good clean sample with very little embryo exposure. A sound sample from a different source was used as the check at Indian Head. The second sample came from Saskatoon, and about 67% of the kernels had their embryos exposed. Apart from this it was a good sample of seed. The third sample came from Codette and carried *H. sativum* on about 10% of the kernels, and 23% of the kernels showed embryo exposure.

The wheat was sown at Indian Head and at Saskatoon, in single rows 18.5 feet in length and replicated 6 times at each place. The seeding was done with a Kemp V-belt rod-row seeder and approximately 200 seeds were sown in each row. The seed treatments were applied in the manner described above for the pot tests.

When the seedlings were in the second or third leaf stage emergence notes were taken. Conditions for germination were more favourable at Indian Head than at Saskatoon as soil moisture was more plentiful. Consequently the seed treated with formalin was damaged more at Saskatoon.

TABLE 8.—THE EFFECTS OF EMBRYO EXPOSURE AND FUNGUS INFECTION ON THE EMERGENCE AND YIELD OF APEX WHEAT, SUBJECTED TO DIFFERENT SEED TREATMENTS

Place	Source of sample	Condition	Check		Ceresan		Formalin		Lunasan	
			Emergence	Yield	Emergence	Yield	Emergence	Yield	Emergence	Yield
			%	gm.	%	gm.	%	gm.	%	gm.
Saskatoon	Melfort	6% cracked	89	177	91	172	78	142	93	183
	Saskatoon	67% cracked	88	174	91	200	52	103	90	196
	Codette	10% *H. sativum* and 23% cracked	84	172	92	209	60	122	92	204
Indian Head	Richlea	18% cracked	91	198	95	224	83	202	95	225
	Saskatoon	67% cracked	86	174	92	207	72	171	93	194
	Codette	10% *H. sativum* and 23% cracked	86	182	85	164	79	174	89	193

The results of these tests, shown in Table 8, while not entirely consistent, indicate that the seed which contained a high percentage of kernels with exposed embryos did not do as well under actual field conditions as sound seed. This was particularly true of the seed treated with formalin before sowing. The mercurial dust treatments appeared to be quite beneficial. The formalin treatment reduced the emergence in all cases and at Saskatoon the yields were reduced also. The seed carrying *H. sativum* also showed considerable embryo exposure which makes it rather difficult to assess the influence of the fungus.

The Comparative Effects of Formalin and Ceresan on Three Samples of Wheat Having Different Percentages of Kernels with Exposed Embryos

For this experiment 3 samples of Regent wheat were used at Saskatoon. The samples varied considerably in the amount of embryo exposure, but they all germinated well (94 to 97%) on blotters. The seed treatments were applied as described above. The seed was sown in the field in plots, each consisting of 5 rows 18.5 feet in length, and at harvest time 1 foot was cut off each end of the rows reducing them to 1 rod in length. There were 5 replications of each plot and these were arranged on the split plot randomized block plan.

In the second-leaf stage the emerged seedlings were counted, and at harvest time yields were taken on the centre 3 rows of each plot. The data secured at Saskatoon are shown in Table 9.

TABLE 9.—EMERGENCE AND YIELD DATA; EFFECTS OF SEED TREATMENTS ON THREE DIFFERENT SAMPLES OF REGENT WHEAT HAVING DIFFERENT PERCENTAGES OF EXPOSED EMBRYOS

Source of sample	Kernels with exposed embryos	Check		Ceresan		Formalin	
		Average emergence	Average yield per acre	Average emergence	Average yield per acre	Average emergence	Average yield per acre
	%	%	bu.	%	bu.	%	bu.
Whitewood	15	79	41.6	77	41.3	62	39.7
Regina	50	73	39.0	80	40.9	48	34.5
Indian Head	85	73	39.0	69	38.7	37	33.3

In this experiment the crop from the severely cracked seed yielded less on the average than that from the moderately or slightly cracked seed. There was no consistent improvement in emergence resulting from treatment of the seed with ceresan. The emergence was greatly reduced by the formalin treatment and the amount of injury was clearly correlated with the amount of embryo exposure. The yields also were reduced by the formalin treatment.

The results of a similar test conducted at Indian Head with different seed are shown in Table 10. The figures for emergence show a distinct negative correlation between the amount of embryo exposure and the total emergence. The ceresan treatment improved the germination slightly while the formalin treatment reduced it quite definitely. The yield results are somewhat contradictory but the plots from severely cracked seed treated with formalin produced considerably less than the checks.

Table 10.—Emergence and yield data; effects of seed treatments on three samples of Renown wheat, having different percentages of exposed embryos

Source of sample	Kernels with exposed embryos	Check		Ceresan		Formalin	
		Average emerg-ence	Average yield per acre	Average emerg-ence	Average yield per acre	Average emerg-ence	Average yield per acre
	%	%	bu.	%	bu.	%	bu.
Wroxton	19	92	33.2	97	32.9	81	31.5
Raymore	66	87	32.5	89	33.4	69	33.8
Lorlie	90	76	32.7	79	32.2	44	26.6

The Comparative Effects of Formalin and Ceresan on Two Composite Samples of Apex Wheat Showing Slight and Moderate Amounts of Embryo Exposure Respectively.

In this test seed from 10 different sources was mixed together for each seed lot. The average amount of embryo exposure in the first lot was about 12%, and in the second lot it was about 55%. The experiment was similar to the one just described in all other respects. The results obtained are recorded in Table 11.

Table 11.—Emergence and yield data; effects of seed treatments on slightly and moderately cracked composite samples of Apex wheat

Place	Kernels with exposed embryos	Check		Ceresan		Formalin	
		Average emerg-ence	Average yield per acre	Average emerg-ence	Average yield per acre	Average emerg-ence	Average yield per acre
	%	%	bu.	%	bu.	%	bu.
Saskatoon	12	73	39.7	80	41.5	64	40.1
	55	71	38.8	73	39.1	57	35.9
Indian Head	12	88	37.3	92	36.5	80	38.6
	55	86	36.1	87	38.0	74	36.0

In this experiment the emergence on the whole was about 14% higher at Indian Head than at Saskatoon. There was a slight but consistent difference in favour of the slightly cracked sample. Ceresan produced a slight increase in total emergence while formalin caused a decided reduction at both places. In the matter of yields, there was on the average a slight difference in favour of the plots from the seed lot with the smaller percentage of exposed embryos, and this was particularly noticeable when the formaldehyde treatment was used.

DISCUSSION

The routine tests described in this paper were designed to provide for the more important aspects of wheat seed examination. The colour of the seed indicates whether or not it was ripened and harvested under favourable conditions and gives some hint as to its germinative capacity and vigour. The importance of having plump, well-filled seed lies chiefly in the ability of the plants from such seed to recover readily if the crop is damaged in the early seedling stage by such agencies as frost or drifting soil. Smudge, a diffuse dark brown discoloration centering around the germ end of the wheat grains, sometimes, but not always, indicates the presence of *H. sativum* in the seed. As this fungus is a vigorous parasite of wheat seedlings, the presence of many smudged kernels in a sample would naturally make one suspicious of it. Blackpoint, an inky black discoloration at the very tip of the seed, is often indicative of a bacterial seed-borne disease, known as basal glume rot, caused by *Phytomonas atrofaciens* (Mc. Cul.) Bergey *et al.* Scab is usually indicated by seeds which are more or less shrunken and whitened. *Fusarium* spp. are considered the cause of this disease in Western Canada. Fortunately the wheat of this region is relatively free from it. These diseases when present in seed grain call for suitable seed treatment before the wheat is sown. Organic mercury dusts are now regarded as the most effective treatments for such infections.

The centrifuge test, when applied as described above to the samples from this province, revealed very little besides the presence of small quantities of bunt spores on about one-third of the samples tested. By sowing a number of these samples in the field and examining the resultant crop, it was found that a trace of bunt spores on the seed in some cases resulted in a trace of bunt in the mature crop and in about an equal number of cases did not. Greater numbers of bunt spores on the seed resulted in heavier infections in the mature crop. Of course it is recognized that a given spore load on the seed will not necessarily produce the same amount of infection under different conditions. Such factors as the temperature of the soil during germination and the variety of wheat concerned greatly influence the amount of infection which develops. In this region it seems advisable to recommend seed treatment for the control of bunt whenever a trace of the spores appears on the seed. However, if a sample is tested and no bunt spores are found, it does not appear to be necessary to spend time and money treating the seed with a fungicide unless other fungi of importance are present. As pointed out above, about two-thirds of all the seed samples tested in this investigation showed no trace of bunt spores. Moreover a very few of them carried an appreciable amount of *H. sativum.*

The incubation test revealed the fact that a considerable proportion of the seed carried *Alternaria* spp. and a miscellaneous assortment of other

fungi, including *H. sativum*, *Fusarium* spp., *Rhizopus nigricans* Ehrenb., *Cladosporium* sp., *Penicillium* spp. and a number of undetermined species. As far as we know, none of these have much significance from the plant disease standpoint, except *H. sativum*, *Fusarium* spp. and *Penicillium* spp., but the parasitic capabilities of the various fungi, which develop on seed under these conditions, are not completely known. Moreover, some of the purely saprophytic soil fungi may subsist on the endosperm of seeds with cracked seed coats and thus deprive the developing seedlings of part of their food supply.

The critical examination of the seed for cracks and holes in the seed coats over the embryo showed that about 25% of all the kernels examined in these investigations had their embryos more or less completely exposed to the action of fungi and fungicides. These fractures commonly occur when the grain is being threshed, but they also may be produced by certain cleaning and handling operations. The practical importance of this situation was studied by means of the experiments described, and the data obtained have a direct bearing on the selection and treatment of seed wheat.

It was found that the emergence of a sample was usually adversely affected when a large proportion of the seeds had their embryos exposed. The decrease in emergence may result from one or more causes, such as the mechanical destruction of parts of the embryos, direct poisoning by the unobstructed penetration of certain chemicals when the seed is being treated with fungicides, and the attack of parasitic fungi such as *H. sativum* on the developing seedling, or of saprophytic fungi such as *Penicillium* spp. on the endosperm in the seed. In certain pot tests, not dealt with in the body of this paper, it was seen that a considerable number of seedlings, developing from seeds with exposed embryos, were much stunted by the action of Penicillium colonies growing in and around the seeds from which these seedlings originated. Under the same conditions a much smaller number of seedlings, from sound seed selected from the same sample, showed similar symptoms. In the field tests, the yields from badly cracked samples were reduced in some cases but often they were just as high as those obtained from sound samples. It appeared, however, that decreases in yield were more apt to occur when such seed was treated with formalin.

Among the seed treatments in common use the formalin treatment is especially liable to injure seeds with exposed embryos. This is amply shown by both the greenhouse and the field experiments reported in this paper, and it has been reported by other investigators. Certain other factors, such as the method of applying the treatment and the dryness of the soil during the germination period, will undoubtedly affect the severity of the injury. At times reports of poor germination of wheat in the field in this district have been investigated. In some cases the low germination could be attributed to wire-worms or dry seed bed, but in other cases it appeared to be due to seed coat fractures and consequent formalin injury. It seems unwise to use the formalin treatment if such seed is to be sown, particularly as certain of the mercurial dust treatments appear to improve its germination.

In the field experiments, reductions in emergence were not always followed by reductions in yield of grain. It appeared that in some cases

the thinner stand was able to utilize all the available moisture and produce just as much grain as the thicker stand. In other cases reductions in emergence were followed by distinct reductions in yield. In weedy fields there would be less likelihood of thin stands of seedlings producing as good yields of grain as thicker stands, because the weeds would get a stronger start and offer more competition than they could against a thicker stand of wheat seedlings. For that reason it probably is advisable to increase the rate of seeding when much embryo exposure exists.

SUMMARY

1. More than 200 samples of seed wheat produced in Saskatchewan were subjected to certain routine tests to ascertain their suitability for seed purposes.

2. These tests detected the presence of various diseases, discolorations and other abnormalities which detract from the value of a sample of seed wheat.

3. The centrifuge test may be used as a means to determine whether or not a given sample requires treatment for the control of bunt.

4. Exposure of the embryo through cracks or holes in the seed coats over the embryo is considered of real importance. It permits the free access of fungi and fungicides to the embryo. The experiments showed that this may result in reduced emergence and diminished yields of grain.

5. When seed with a high percentage of exposed embryos must be used, it would seem advisable to avoid the formalin treatment and use one of the mercurial dust treatments. Under certain conditions it may be advisable also to increase the rate of seeding.

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SOME PRELIMINARY EXPERIMENTS ON THE INSECTICIDAL VALUE OF CERTAIN PLANT EXTRACTS, MORE PARTICULARLY THOSE OF *DELPHINIUM BROWNII* RYDBERG[1]

H. T. Stultz[2] and N. A. Patterson[3]

Dominion Entomological Laboratory, Annapolis Royal, N.S.

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In August, 1934, some exploratory tests were made with a number of plant alkaloids and alkaloid mixtures which it was thought might prove to have valuable insecticidal properties. These materials included the alkaloids tetrahydropolmatine, protopine, dicentrine, and corydine in the form of crystalline hydrochlorides; and the total alkaloids of *Lobelia inflata* L., *Menispermum canadense* L., and *Delphinium brownii* Rydb. in the form of 3% amorphous hydrochloride solutions. They were tested against two diverse insect forms, namely unidentified mosquito larvae and potato beetle larvae.

Tests with mosquitoes were made by keeping larvae, one-half to three-quarters grown, in vials of water containing different concentrations of each of the experimental materials. The potato beetles were sprayed in the laboratory, drained off and set aside in feeding cages for observation. Nicotine sulphate was used as a standard of comparison. Each dilution of the materials was made to contain equal weights of the solids, i.e., hydrochloride crystals, amorphous alkaloids or nicotine in the nicotine sulphate solution. The alkaloids of *Lobelia inflata* were found to be about as toxic as nicotine sulphate to both mosquito larvae and potato beetle larvae, while the alkaloid of *Delphinium brownii* Rydb. was more toxic than either. The other materials were somewhat less toxic than nicotine sulphate; listed in descending order of toxicity they are dicentrine hydrochloride, protopine hydrochloride, alkaloids of *M. canadense* L., corydine hydrochloride, and tetrahydropolmatine hydrochloride.

Although, because of limitations of time and available materials, these tests were not extensive enough to permit any definite evaluation of the poisonous properties of the alkaloids, it was thought they did furnish a relative index of their toxicity to mosquito larvae and potato beetle larvae.

The most promising of the compounds tested appeared to be the alkaloid of *D. brownii*. *L. inflata* is evidently quite toxic against the insects used, but would be difficult to obtain in commercial quantities for insecticides, whereas the commercial production of the *D. brownii* alkaloid seems more feasible, particularly as the total alkaloid content of this plant is 0.5% (1).

In order to continue experimentation with this material, a further supply was obtained of about 100 cc. of a 25% solution of carefully purified alkaloid of *D. brownii*.

In the 1935 experiments this alkaloid was compared directly with nicotine sulphate as a contact poison, an ovicide, a stomach poison (residual

[1] Contribution No. 2059, from the Division of Entomology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.
[2] Agricultural Scientist.
[3] Assistant Entomologist.

effect) and a fumigant. As great a range of insect forms were used as were readily available. Where these two materials were tested in liquid form they were generally, in each series of tests, used over a range of from 3 to 5 concentrations, indicated in this paper as parts by weight of actual alkaloid in water, i.e. 1 : 250, 1 : 1000, etc.

SPRAYS

Compared as Contact Insecticides

ORCHARD TENT CATERPILLAR, *Malacosoma americana* Fab. Used at dilutions of 1 : 1000 to 1 : 5000 delphinium was practically non-toxic whereas nicotine showed considerable toxicity.

IMPORTED CURRANT WORM, *Pteronidea ribesii* Scop. At concentration of 1 : 1000, 1 : 5000 and 1 : 10,000, both nicotine and delphinium used alone and in combination with hydrated lime gave irregular and inconsistent results. A nicotine-spreader (Igepon AP extra) combination, each component used at a dilution of 1 : 1000, produced complete control in 48 hours, whereas it took 6 days for the corresponding delphinium combination to produce the same effect. When used alone Igepon was somewhat more toxic than either delphinium or nicotine alone at the same concentration (1 : 1000), but did not produce complete control at the end of 6 days.

POTATO BEETLE LARVAE, *Leptinotarsa decemlineata* Say. Only at a concentration of 1 : 500 did delphinium give any indication of a toxic effect, but this was not as pronounced as that of nicotine when used at half that strength (1 : 1000).

GRAY-BANDED LEAF ROLLER, *Argyrotaenia mariana* Fern. In the case of very young larvae nicotine was fairly effective at concentrations of 1 : 500 1 : 1000 and 1 : 2000 whereas the delphinium alkaloid was only slightly toxic. In the case of older larvae ($\frac{1}{2}$ inch long) neither meterial gave any control whatever.

GREEN APPLE APHID, *Aphis pomi* DeG. The delphinium alkaloid was comparatively ineffective even when used at a concentration of 1 : 250. In one series of tests results obtained 72 hours after spraying are shown in Table 1.

TABLE 1.

Spray material	No. of aphids treated	Percentage dead
		%
Delphinium alkaloid 1÷250	350	15
Delphinium alkaloid 1÷500	425	25
Delphinium alkaloid 1÷500 plus castile soap 4÷1000	290	97
Delphinium alkaloid 1÷1000 plus castile soap 4÷1000	270	95
Castile soap 4÷1000	75	95
Castile soap 2÷1000	300	75
Check	500	6

In comparison, nicotine used at 1 : 10,000 resulted in 90 to 100% mortality within 48 hours after spraying. Tests made against the rosy apple aphid (*Anuraphis roseus*, Baker) and a cabbage aphid also showed the delphinium alkaloid to be comparatively ineffective against these species.

Rose Leafhopper, *Typhlocyba rosae* L. The delphinium alkaloid is apparently as toxic as nicotine sulphate against this insect. Two series of experiments were conducted on heavily infested roses with these materials alone and in combination with hydrated lime (10 : 1000) or Igepon AP extra, 1 : 1000. Neither of the adjuvants materially increased the effectiveness of either nicotine or delphinium. At a concentration of 1 : 1000 either material alone resulted in practically 100% control of the leafhopper within 48 hours after treatment.

Apple Mealy Bug, *Phenacoccus aceris* Signoret. In the case of nearly mature females, sprayed when on apple twigs shortly before the buds broke in the spring, and also about blossom time, no control whatever was obtained with either nicotine or delphinium used at several dilutions ranging from 1 : 500 to 1 : 10,000. Both materials, however, were quite toxic to very young nymphs on apple leaves, when sprayed in the field during the month of August. In Table 2 is given the number of living nymphs found per 100 leaves taken from infested branches part of which were sparyed as indicated and part left unsprayed. Each sprayed group of leaves had its corresponding check of unsprayed leaves growing nearby.

Table 2.

Concentration of spray materials	No. of living nymphs per 100 leaves					
	Nicotine	Check	Control	Delphinium	Check	Control
			%			%
1 ÷ 1000	55	466	88.2	118	433	72.8
1 ÷ 1000 plus fish oil 4 ÷ 1000	41	339	88.0	110	410	75.4
1 ÷ 500 plus fish oil 4 ÷ 1000	22	905	97.6	45	534	91.6
1 ÷ 1000 plus spreader* 4 ÷ 1000	45	460	90.2	109	1047	89.6

* SS3 Dupont.

European Apple-sucker Nymph, *Psyllia mali* Schmid. Two series of field tests were run, involving the spraying of heavily infested apple twigs containing 10 or more blossom clusters per plot. The control obtained with the delphinium alkaloid approximated that of nicotine. Thus, in one series of tests on a heavily infested tree, nicotine at dilutions of 1 : 1000, 1 : 2500, 1 : 5000, 1 : 7500, and 1 : 10,000 resulted in controls of approximately 92, 96, 94, 77 and 81% respectively, whereas the delphinium alkaloid used at the same dilutions gave controls of approximately 94, 90, 86, 84 and 82%. Where hydrated lime (10 : 1000) was added to the spray solutions the following are the corresponding approximate controls produced: Nicotine, 97, 97, 98.5, 96.5, and 94%; delphinium, 98, 97, 89, 90, and 80%.

Mosquito Larvae, *Aedes cantator* Coq. During the later part of May, in 14 comparative tests, with dilutions ranging from 1 : 10,000 to 1 : 100,000, delphinium alkaloid invariably proved less toxic than nicotine to mosquito larvae. After 4 days in the stronger concentrations of 1 : 10,000 and 1 : 25,000 the percentages of living larvae were respectively 10 and 15 in nicotine and 18 and 50 in the delphinium alkaloid solutions. On the

other hand, the results of a repetition of these tests carried out on July 9 indicated that the delphinium alkaloid was quite as toxic as nicotine if not more so. On this date solutions 47 days old were tested, and the results indicated that whereas the delphinium solutions had become practically non-toxic, the nicotine solutions seemed to be quite as toxic as when freshly made up. Solutions of the delphinium alkaloid which had stood four days suffered no appreciable loss of toxicity.

Compared as Stomach Insecticides

When used without adjuvants at 1 : 500, and in some cases at weaker dilutions, against the larvae of the imported currant worm, potato beetle, fall webworm (*Hyphantria cunea* Drury) and the imported cabbage worm (*Pieris rapae* L.) the delphinium alkaloid proved generally more toxic than nicotine. It was also, generally speaking, a more effective feeding repellent as indicated by the comparative amounts of leaf area eaten, even when few larvae were killed.

When potato foliage carrying potato beetle eggs was sprayed on the upper sides, neither material affected the hatching of the eggs on the under sides but the larvae after hatching disappeared first from the delphinium-sprayed foliage and also did considerably less egg-shell and leaf feeding. Thus on leaves sprayed with nicotine at dilutions of 1 : 200, 1 : 400 and 1 : 600, 20, 90 and 50% respectively of the egg-shells were eaten, whereas on leaves sprayed with delphinium at these dilutions 0, 10, and 25% respectively were eaten. No living larvae remained on any of the delphinium-sprayed leaves after 24 hours, whereas on those sprayed with nicotine larvae remained as long as 3 days. On two lots of the delphinium sprayed leaves (1 : 200 and 1 : 400) the material had been on the plant for 5 days before the eggs hatched.

A somewhat similar series of tests was run against gray-banded leaf roller larvae. Apple leaves carrying leaf roller eggs were put in separate vials closed with cotton plugs; at the same time apple twigs with 7 to 10 leaves each were sprayed with different concentrations of each material and left in the insectary in jars of water. The eggs hatched over a period of 2 to 9 days. When the larvae in a vial had hatched one of the sprayed leaves was put in with them. In a pair of tests where the spray at 1 : 2500 had been applied 2 days previously, 80% of the larvae were killed by the delphinium alkaloid and 100% by nicotine. The residue of delphinium, 1 : 1000, 11 days after spraying was apparently non-toxic whereas the same dilution of nicotine 9 days after spraying gave complete control of newly hatched larvae.

Larvae of the imported cabbage worm and of the fall webworm were placed on leaves of their natural food plants sprayed with mixtures in which nicotine and the delphinium alkaloid at 1 : 500 were combined with fish-oil (4 : 1000) or Igepon AP extra (4 : 1000). In the case of both insects the delphinium alkaloid fish oil combination was a more effective feeding repellent than the delphinium alone, nicotine, or the nicotine-fish oil combination. The use of Igepon as an adjuvant with these two poisons seemed to decrease their effectiveness.

Some rather promising results were obtained when the delphinium alkaloid was adsorbed by activated carbon at the rate of 1 part by weight of the alkaloid to 5 parts of carbon and diluted with water to give a 1 : 500 delphinium alkaloid concentration. In the first series of tests, in which it was used against the gray-banded leaf roller and the fall webworm, this combination proved very toxic. In the case of the fall webworm at least, the degree of toxicity compared favourably with that obtained from calcium arsenate, 1 pound metallic arsenic per 100 gallons of water. The apple leaves of the original test carrying this mixture were reinfested with fall webworm larvae 1 and 2 weeks after treatment and little loss in toxicity was indicated. Subsequent tests with this combination were not as promising, apparently because the leaves would not retain as heavy a coverage of carbon particles. The addition of fish oil 1 : 100 did not overcome this difficulty. Where equal coverage was obtained with these combinations the delphinium alkaloid was considerably more effective than nicotine both as a stomach poison and as a feeding repellant.

When nicotine and delphinium were used in conjunction with a colloidal clay (bentonite) the nicotine-bentonite mixture proved the more effective of the two. It was, however, not nearly as effective as the delphinium-carbon mixture.

Compared as Ovicides

All the ovicidal tests were conducted at the laboratory, the small amount of delphinium alkaloid available making it impossible to duplicate them in the field.

Eye-spotted Budmoth, *Spilonota ocellana* D. & S. When eggs were sprayed with these materials at dilutions of 1 : 500, 1 : 1000 and 1 : 2000, the following percentages of eggs failed to hatch respectively:

Nicotine	—61.5, 60, and 40%.
Delphinium alkaloid	—10, 0, and 0%.
Check	0%.

Gray-banded Leaf Roller. After being sprayed with nicotine 1 : 1000, 59% of the eggs failed to hatch whereas with the delphinium alkaloid at this strength all eggs hatched.

Potato Beetle. Delphinium was only slightly, if at all, toxic to the eggs whereas nicotine, despite some inconsistent results, was undoubtedly quite toxic, particularly when used in conjunction with hydrated lime. However, after hatching, the larvae disappeared sooner from the delphinium sprayed foliage and less leaf feeding was done.

DUSTS

Nicotine sulphate and delphinium alkaloid dusts were made up containing 2 per cent actual alkaloids in hydrated lime. The test insects were dusted directly with the following results:

Cabbage Aphid. Whereas the nicotine dust resulted in at least 90% control within 48 hours, the delphinium dust did not give over 10% control.

GREEN APPLE APHID. The nicotine dust resulted in 100% control in 24 hours whereas not over 3% control was obtained with the delphinium dust.

POTATO BEELTE LARVA. The delphinium dust had no apparent toxic effect on this insect whereas the nicotine dust immobilized them for 24 to 48 hours, although all later recovered and became quite active.

FUMIGANTS

The relative values of nicotine sulphate and the delphinium alkaloid as fumigants were tested in two ways.

1. The 2% dusts previously described were scattered around the inside edges of large petri dishes. The test insects, *Aphis pomi*, were put in small clean petri dishes resting inside the larger dishes which were then covered and left for 24 hours.

A group of 131 aphids put in the nicotine sulphate chamber were all dead at the end of 24 hours. In fact, none had moved from the leaves on which they rested when put in the chamber. Out of 125 aphids in the delphinium chamber only 2 were dead at the end of 24 hours. Only 1 of 28 aphids which had left the original container and were wallowing in the dust was dead. At the end of 48 hours 92.2% of the 65 aphids then in the dust were dead as compared to 2 dead out of 33 in the dust in the hydrated lime check chamber.

2. Three closed chambers for comparing these two materials with each other and with a check were formed by inverting large candy jars over a common base formed by a large piece of sheet iron. The base was then heated and a small quantity of full strength nicotine sulphate was placed on the base under one jar; a small quantity of the delphinium stock was placed under a second while the third was left as a check. Insects on apple foliage were then put in the jars in such a way that they would not come in contact with the insecticides.

GREEN APPLE APHID. Aphids left in the nicotine sulphate fume chamber for 20 minutes were all dead within 15 hours whereas none of those put in the delphinium chamber were dead within this time. At the end of 48 hours the percentage dead for this and the check chamber were approximately the same, i.e., 15%.

FALL WEBWORM. Those left in the nicotine chamber were all immobilized in 2 hours and all dead in 4 hours whereas all were alive in the delphinium and check chambers at the end of 48 hours. (Heating period, 4 hours.)

SUMMARY

1. Preliminary tests were made with 7 different plant alkaloids or alkaloid mixtures which were directly compared with nicotine sulphate as a standard for their insecticidal value against mosquito and potato beetle larvae. Of them all, the alkaloid of *Delphinium brownii* Rydb. was considered the most promising for further study.

2. The results of more extensive tests with the delphinium alkaloid indicate that as a contact insecticide it cannot be expected to excel nicotine sulphate. Against many of the insect forms on which it was so tested it proved distinctly inferior, notably so in the case of aphids.

3. The results indicate that the delphinium alkaloid may be expected to prove more effective as a stomach poison and feeding repellent than nicotine sulphate, particularly if combined with an adhesive such as fish oil or if adsorbed on activated carbon particles.

4. The delphinium alkaloid has no apparent value as a fumigant.

5. Water solutions of the delphinium alkaloid do not retain their toxicity on standing as long as those of nicotine sulphate. Some of the results also suggest that spray residues of the delphinium alkaloid do not retain their toxicity as long as those of nicotine sulphate, but this defect might be overcome, to some extent at least, by the adsorption of the alkaloid on activated carbon.

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REFERENCE

1. MANSKE, RICHARD H. F. An alkaloid from *Delphinium brownii* Rydb. Canadian J. of Research, B, 16 : 57-60. 1938.

AUTHOR INDEX